Biological and Conference Opinion on the Registration of Methomyl Pursuant to the Federal Insecticide, Fungicide, and Rodenticide Act

Photo credit: Tessenderlo Kerley

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A

APHIS

Animal and Plant Health Inspection Service ....

atm-m^3/mol

atmosphere cubic meter per mole ....

B

BE

Biological Evaluation ....

C

CalPUR

California Pesticide Use Reporting

CBD

Center for Biological Diversity

CDL

Crop Data Layer

CEQ

Council on Environmental Quality

CERCLA

Comprehensive Environmental Response, Compensation and Liability Act

CoA

Census of Agriculture

CONUS

Conterminous United States

D

DDT

dichlorodiphenyltrichloroethane

DT_{50}

Half-life

E

ECOTOX

ecotoxicology database

EEC

estimated environmental concentration

EPA

Environmental Protection Agency

ESA

Endangered Species Act

F

FIFRA

Federal Insecticide, Fungicide, and Rodenticide Act

H

HC$_{05}$

hazardous concentration 5th percentile

I

IPCC

Intergovernmental Panel on Climate Change

K

K$_{FOC}$

organic carbon-water partition coefficient

K$_{OWS}$

octanol-water partition coefficients

L

L/kg

Liters per kilogram

LAA

may affect, likely to adversely affect

lbs a.i./acre

pounds of active ingredient per acre

LC$_{50}$

median lethal concentration

LD$_{50}$

median lethal dose

LOAEC

Lowest Observed Adverse Effect Concentration

M

mg a.i./L

milligrams active ingredient per liter

MRID

Master Record Identifier

N

NAFTA

North American Free Trade Agreement

NAS

National Academies of Science

NASS

National Agricultural Statistics Service

NE

no effect

NLAA

may affect, not likely to adversely affect

NMFS

National Marine Fisheries Service

NOAEC

No Observed Adverse Effect Concentration

NRC

National Research Council

P

PAHs

polycyclic aromatic hydrocarbons

PBDEs

poly-bromated diphenyl ethers

PCBs

polychlorinated biphenyls

PID

proposed interim registration review decision

PRZM5

Pesticide Root Zone Model

Q

QSAR

R

ROWs

rights-of-way

RPAs

Reasonable and Prudent Alternatives

RUPs

Restricted Use Pesticides

S

Service

U.S. Fish and Wildlife Service

SLN

Special Local Needs

SMCRA

Surface Mining Control and Reclamation Act

SSD

Species Sensitivity Distribution

T

TKI

Tessenderlo-Kerley, Inc.

T-REX

Terrestrial Residue Exposure

U

UDLs

use data layers ....

USDA

U.S. Department of Agriculture...

V

VVWM

Variable Volume Water Model ....

W

WACAP

Western Contaminants Assessment Project..

INTRODUCTION

This document represents the U.S. Fish and Wildlife Service's (Service) Biological and Conference Opinion (Opinion) based on our review of the Environmental Protection Agency's (EPA) proposed national registration of methomyl and its effects on endangered and threatened species and designated critical habitat in accordance with section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.). On March 31, 2021, EPA submitted the necessary information and a request to initiate formal section 7 consultation.

We based this Opinion on information in the final Biological Evaluation (BE) for methomyl, many interagency meetings, workshops and conference calls, and other sources of information as described herein. The methods employed in EPA's BE follow the Revised Method for National Level Listed Species Biological Evaluations of Conventional Pesticides (referred to as the "Revised Method")[1]. In March 2020, EPA released the Revised Method for National Level Listed Species Biological Evaluations of Conventional Pesticides. EPA used the Revised Method to conduct the draft BE for methomyl. The Revised Method incorporates recommendations from the National Research Council (NRC) of the National Academies of Science (NAS) for the process EPA developed with the Service and National Marine Fisheries Service (NMFS) related to determining effects of the action to listed species and critical habitats. A preliminary approach developed in 2015 is referred to as the Interim Method, which was applied to the first three national-level pilot BEs (for chlorpyrifos, diazinon and malathion; discussed in more detail below in the Consultation Background section). EPA's "lessons learned" during the first three pilot BEs provided the starting point for development of the Revised Method via public comments provided through stakeholder meetings, through the docket on the draft BEs for chlorpyrifos, diazinon and malathion, and through the docket on the proposed Revised Method; comments received during consultation with federally recognized tribes; and comments provided by the Service, NMFS, and the U.S. Department of Agriculture (USDA). On March 17, 2020, EPA released the draft BE for methomyl for public comment. EPA received public comments on the proposed Revised Method and the methomyl BE through July 2, 2020, which included a 45-day extension of the original public comment period. Updates to the Revised Method and updates that were specific to methomyl were incorporated in the final BE. A complete record of this consultation is on file at the Services' Headquarters office in Falls Church, Virginia.

Due to the complexity and duration of consultation and the proposed action, and ongoing consideration of listing decisions anticipated during and immediately following the consultation period, EPA and the Service (the Agencies) agreed to evaluate effects to proposed species and critical habitat and candidate species via conferencing, using similar methods for their analyses of listed species and designated critical habitats in both the BE and Opinion.

CONSULTATION BACKGROUND

The ESA section 7(a)(2) consultation process regarding the registration of pesticides pursuant to the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) has a long history as discussed

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[1] Available at: https://www.epa.gov/endangered-species/revised-method-national-level-listed-species-biological-evaluations-conventional

below. For more than a decade, the Agencies struggled unsuccessfully to reach consensus on the approaches for assessing the risks of pesticides on endangered and threatened species and their critical habitat. This led to stalled discussions between EPA and the Service and bouts of inactivity on pesticide consultations. The lack of progress resulted in litigation by various non-governmental organizations. Subsequently, the Agencies asked the National Research Council of the NAS to evaluate scientific and technical aspects of determining the risks to endangered and threatened species. This section provides a short summary of pesticide litigation related to ESA compliance for FIFRA registration, and the NAS report that led to a path forward for the consultation process.

Pesticide Litigation Summary

The pesticide lawsuits against the Service were preceded by lawsuits against EPA for failure to consult on pesticide registrations. The first of these suits, filed in 2002, alleged failure to consult on the effects of 66 pesticides on the California red-legged frog in CBD v. Johnson, No. 02-cv-1580-JSW (N.D. Cal.). The Center for Biological Diversity (CBD) and EPA settled this suit in 2006, and EPA agreed to make effect determinations on the 66 pesticides. Between October 2007 and October 2008, EPA requested initiation of formal consultation on the effects of more than 30 pesticides on the California red-legged frog. As mentioned above, the Agencies did not agree on the approach to assess the risk of pesticides on endangered and threatened species, and in a letter dated January 14, 2009, the Service informed EPA that we did not have the necessary information to initiate formal consultation.

The CBD filed a second lawsuit in 2007, CBD v. EPA, No. 3:07-cv-02794-JCS (N.D. Cal.), in which the plaintiff sought to compel EPA to initiate consultation on the effects of 75 pesticides on 11 federally endangered and threatened species in the San Francisco Bay area and to enjoin EPA from permitting the use of the pesticides in the area until consultation was completed. In May 2010, EPA and the CBD reached a settlement. EPA agreed it would complete effects determinations, under a set schedule, on the 75 pesticides and initiate consultation on pesticides for which “may affect” determinations were made. By July 2013, EPA had completed effects determinations for all but 16 of the 75 chemicals. In 2015, the parties amended their agreement to allow EPA to focus its effects determinations on four pesticides (atrazine, simazine, propazine, and glyphosate) for all endangered and threatened species and to complete BEs for the identified pesticides by June 30, 2020.

The Service became a part of the litigation in 2011 when the CBD filed a complaint against the Service and EPA, (CBD v. FWS, No. 3:11-CV-5108-JSW [N.D. Cal.]). The suit alleged failure to consult on the effects of 64 pesticides on the California red-legged frog. On November 4, 2013, the CBD, the Service, and EPA agreed to complete consultation on the effects of two pesticides on the California red-legged frog within a year of the court’s approval of the agreement and on an additional five pesticides within 2 years. Following the NAS report and recommendations on the pesticide consultation process (described further below), the Agencies decided it would be more effective and efficient to conduct national consultations on the effects of individual pesticides on all protected resources pursuant to the ESA rather than consult on multiple pesticides considering only one or a few species at a time. On July 28, 2014, the CBD agreed to amend the 2013 settlement agreement so that EPA and the Service could conduct nationwide consultations on five pesticides (chlorpyrifos, diazinon, malathion, carbaryl, and methomyl) rather than focus on the effects of seven pesticides on the California red-legged frog.

NAS Report and Path Forward

In September 2010, the Agencies, NMFS, and the USDA jointly requested the NAS to examine scientific and technical issues associated with determining the risk of pesticide registration and use to endangered and threatened species protected under the ESA. The Agencies asked the NAS to provide advice on a range of subjects related to risk assessment and the consultation process, including:

(1) identifying best available scientific data and information;

(2) considering sublethal, indirect and cumulative effects;

(3) assessing the effects of chemical mixtures and inert ingredients;

(4) using models to assist in analyzing the effects of pesticide use;

(5) incorporating uncertainties into the evaluations effectively; and

(6) using geospatial information and datasets in the course of the assessments.

The NAS released its report, entitled "Assessing Risks to Endangered and Threatened Species from Pesticides," on April 30, 2013[2]. It had recommendations on scientific and technical issues related to pesticide consultations under the ESA and FIFRA. Since then, the Agencies worked to implement the recommendations. Joint efforts to date include collaborative relationship building between the Agencies; clarified roles and responsibilities for the Agencies; agency processes designed to improve stakeholder engagement and transparency during the review and consultation processes; multiple joint agency workshops and meetings resulting in interim approaches to assessing risks to endangered and threatened species from pesticides; a plan and schedule for applying the interim approaches to a set of pesticide compounds; and multiple workshops and meetings with stakeholders to improve transparency as the pesticide consultation process evolves. While the Agencies continue their efforts to improve the consultation process, this consultation has incorporated the report's overarching recommendation to implement a three-step risk assessment and consultation approach. This fundamental approach includes the following steps:

1. In Step 1, EPA makes the no effect/may affect determination. If EPA determines that a pesticide's registration will have no effect on any endangered or threatened species or their designated critical habitats, it may move forward with a pesticide's registration without further consultation with the Service or NMFS. We reviewed EPA's no effect

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[2] The NAS report with recommendations is available on the National Academy of Sciences website using the following hyperlink: http://www.nap.edu/catalog.php?record_id=18344.

determinations for species and designated critical habitats and adopt their determinations unless otherwise noted in our Concurrence (Appendix A).

2. In Step 2, if EPA determines that a pesticide may affect a listed species or its designated critical habitat, the potential impact is assessed to determine whether species or their designated critical habitats are likely to be adversely affected. The EPA initiates formal consultation for species or their designated critical habitats that are likely to be adversely affected and seeks concurrence from the Service on its "not likely to adversely affect" determinations.

3. In Step 3, using the information provided by EPA in its Step 2 analysis, the Service and NMFS make jeopardy and destruction or adverse modification determinations for the species and designated critical habitats that EPA determined are likely to be adversely affected.

CONSULTATION HISTORY

The following timeline describes early coordination and informal consultation between the EPA and the Service and identifies key points in the consultation process for the proposed national registration review of methomyl. While many of the events related to the NAS report and subsequent activities discussed in the paragraphs above form the consultation history for this biological opinion, the listing below is focused on the more recent activities.

Early Coordination on EPA's Biological Evaluation:

August 31, 2016	EPA and the Service meet with the methomyl registrant, DuPont, to discuss some additional ecotoxicity data they will be providing to EPA.
September - October 2016	EPA and the Services begin to discuss the approach for the BEs for the next two carbamate pesticides outlined in the Pesticide Litigation Summary above, carbaryl and methomyl.
December 5, 2017	Presentation to the Service on California's Prescribe and California Pesticide Use Reporting (CalPUR) program and to learn about California's Pesticide Regulation's Endangered Species Custom Realtime Internet Bulletin Engine.

January 4, 2018	Presentation to the Service on California's on CalPUR Prescribe and CalPUR programs and California's Pesticide Use Reporting database.
February 26th, 2018	Pesticide Usage Meeting to discuss the usage data provided to the Service and NMFS from EPA and how to utilize them to assess effects on threatened and endangered species. Participants: staff, management, solicitors, and senior leadership from DOI, EPA, NMFS, and USDA, and Council on Environmental Quality (CEQ).
December 10, 2018	Briefing on Agricultural Usage Data - Meeting held to update interagency management on progress defining the agricultural portion of the proposed action area incorporating usage data.
October 2018-November 2019	The Service participated in various stakeholder meetings on several topics pertaining to a path forward for pesticide consultations.
July 2019	Meeting with EPA to discuss the application of the usage data available for Hawai'i, Alaska, Puerto Rico, and other territories.
August 27th, 2019	Interagency meeting with Kynetec. Presentation to the Service and NMFS: 1) a general overview of the Agrotrak data, 2) the survey methodology and statistical methods used, and 3) address Service and NMFS questions submitted prior to the meeting regarding method variability, survey

	procedures/protocols, and the survey design and sampling.
March 2020	EPA provides the Service with the draft BE for methomyl and carbaryl
October 1, 2020	The Service meets with the methomyl registrant, Corteva, to discuss the following:
	• Begin discussions on how Corteva can help FWS with information to support the methomyl consultation. • Corteva as a company and relation to Dow Chemical and DuPont. • Corteva as lead registrant and manufacturer of methomyl. • Status of the methomyl consultation. • Usage data for methomyl. • Species refined range maps. • Voluntary conservation measures.
March 31, 2021	EPA provides the Service with the final BEs for carbaryl and methomyl.
June 29, 2021	The Service agrees to an extension of the methomyl consultation with EPA and the 3 technical registrants, Corteva Agriscience, Sinon Corporation, and Rotam Agrochemical Company.

August 18, 2021	The Service and EPA meet to discuss questions on the NE and NLAA determinations in the BE.
June 1, 2022	Interagency workshop between EPA, the Service, NMFS, and USDA to discuss aligning methodologies for usage data, including California Department of Pesticide Registration data
August 31, 2022	Tessenderlo-Kerley, Inc. (TKI), Sinon Corporation, and Rotam Agrochemical Company, the current registrants for methomyl, provide EPA with letters outlining their commitment to specific label changes for spray drift mitigations.
September 29, 2022	EPA provides the Service with the proposed revisions to the proposed interim registration review decision (PID) document containing revisions to the methomyl labels. This document also contains a discussion of impacts to a small subset of species considered as vulnerable and proposed early mitigations for these species as an alternative to Reasonable and Prudent Alternatives (RPAs).
November 1, 2022	EPA and the Service hold an initial meeting to discuss EPA's pilot assessment for methomyl to assess impacts from methomyl to species and identify mitigations for species or critical habitats that EPA had determined are may affect, likely to adversely affect (LAA).

November 2022 – June 2024	EPA and the Service meet regularly to discuss methomyl where topics include: • Screening approach to determine species vulnerable to the effects of methomyl and to identify upfront potential mitigations. • How to approach the analysis for Pacific and Caribbean island species using the available agricultural use and usage information. • Methodologies to incorporate mandatory pesticide usage reporting data from the California Department of Pesticide Registration.

CONCURRENCE

In their BE for methomyl, EPA provided determinations of “no effect (NE)” for 281 listed species (see Appendix B, Table 1) and 236 designated critical habitats. Similarly, EPA made “may affect, not likely to adversely affect (NLAA)” determinations for 489 listed, proposed, and candidate species and 274 proposed or designated critical habitats under Service jurisdiction. Our discussion of these species and critical habitats is attached in Appendix B.

BIOLOGICAL OPINION

DESCRIPTION OF THE PROPOSED ACTION

The proposed federal action addressed in this Opinion (hereafter, the proposed action) is the registration review of methomyl under FIFRA. Pursuant to FIFRA, before a pesticide product may be sold or distributed in the United States, it must be exempted or registered with a label identifying approved uses by EPA's Office of Pesticide Programs. Once registered, a pesticide may not legally be used unless the use is consistent with directions on its approved label(s). The EPA authorization of pesticide uses are categorized as FIFRA section 3 (new product registrations), section 18 (emergency use), or 24(c) Special Local Needs. FIFRA requires chemicals registered under section 3 and section 24(c) to have their registrations reviewed periodically. As EPA has adopted a 15-year timeframe to review pesticides, the Service considers the duration of the proposed action to be 15 years. The following chemical-specific descriptions are taken largely from EPA's BE for methomyl.

For this pesticide, the proposed action includes registration review of the uses, as described by product labels, of all pesticide products containing methomyl as the active ingredient (Table 1). Four major degradates (i.e., methomyl oxime, acetonitrile, acetamide and CO_2) were detected in various environmental fate studies, but these degradates do not contain a N-methylcarbamate functional group. Furthermore, based on previous Quantitative Structure-Activity Relationship (QSAR) analyses, the degradates are estimated to be less toxic than the parent. Thus, methomyl has no degradates that are considered residues of toxicological concern. The proposed action also includes all authorizations for use of pesticide products, including the use of existing stocks, and active labels of products containing the active ingredient. A complete listing of product uses is found in the *Agricultural and Non-agricultural Use* sections.

In their BE, EPA considered the likely use types of the chemical over the duration of the proposed action, although the Agencies recognized that future uses are difficult to predict with either accuracy or precision, particularly as more time passes. Thus, future uses have been addressed to the extent possible in EPA's BE where the geographic distribution and magnitude of exposure (including application rate and methods of application) have been included in the scope of the assessment. If new uses, rate increases, or an application method that increases exposure beyond what was addressed in the BE and this Opinion are approved or proposed, re-initiation of consultation may be required.

The purpose of the proposed action, as noted in the BE, is to provide tools for pest control on food and feed crops as well as for other non-agricultural uses, under FIFRA, that do not cause unreasonable adverse effects to the environment throughout the United States and affiliated territories. For additional information on the registration and registration review processes, see section 1 in the Problem Formulation of the BE. The following sections describe the proposed action in greater detail and are taken largely from the BE for methomyl.

Labeled Uses

Use data are based on registered product labels and include pesticide application information relevant to a treatment site *(e.g.,* an orchard). EPA determined the uses based on registered labels and define crop or non-crop sites to which a pesticide may be applied. Use data also describe the maximum application rates, method (*e.g.,* aerial or ground spray), re-treatment intervals and number of applications that may occur according to registered product labels.

Methomyl is an insecticide used on a wide variety of terrestrial food and feed crops, terrestrial non-food crops, greenhouse food/non-food, and non-agricultural indoor and outdoor sites. There are currently 3 active registrants of methomyl with 34 active product labels (16 under Section 3s, 18 under Special Local Needs), which include formulated products and technical grade methomyl (see APPENDIX 1-1 of the BE). All the formulated methomyl products, with the exception of the fly bait products, are Restricted Use Pesticides (RUPs) – meaning that they can only be applied by, or under the supervision of, a certified applicator. Methomyl can be applied in liquid form, granular (for application on corn only), as scatter bait, within bait station, or as a brush-on paste. It can generally be applied from emergence to harvest for most crops. Aerial and ground application methods (including broadcast, soil incorporation, orchard airblast, and chemigation) are allowed. Registered labels require applications to use a buffer of 25 feet for ground and 100 feet for aerial applications around natural and artificial bodies of water. Additionally, granular products require a 25-foot (ground) buffer zone adjacent to waterbodies (see APPENDIX 1-2 of the BE for details). Additional label restrictions for individual crops include restrictions on minimum temperature and plant height at application, in addition to preharvest interval, retreatment interval, number of applications, and maximum application volume.

Table 1. List of Current Methomyl Registrations

Draft Table 1 Current
Methomyl registratior

Uses

The EPA developed a list of all current registered uses for methomyl (Table 2 and Appendix 1-2 of the BE), which reflects all currently registered labels. In general, current single maximum methomyl application rates do not exceed 0.9 lbs a.i./acre nationwide for flowable formulations; however, a single application rate of 1.5 lbs a.i./acre is currently permitted for corn and sweet corn use patterns for granular formulation. The maximum annual rate of methomyl that may be applied to a crop site is 21.6 lbs a.i./acre for broccoli in Arizona and cauliflower as well as cabbage in California. Other notable application rates or frequencies include a maximum 16.2 lbs a.i./acre for alfalfa from a single application limit of 0.9 lbs a.i./acre, but with a maximum of 18 applications per year. Similarly, a maximum application rate of 16.2 lbs a.i./acre per year for green onion in Arizona and California and for summer squash in Arizona, California, Florida, and Georgia. Also of note is a maximum application rate of 14.4 lbs a.i./acre per year for spinach in Arizona and California from a single application rate of 0.9 lbs a.i./acre for a maximum of 16 applications and the same for radishes with a maximum single application rate of 0.45 lbs a.i./acre, but with a maximum of 32 applications per year in Florida.

Table 2. Master Use Summary detailed

Draft Table 2 Master
Use Summary detaile

Agricultural Uses

Methomyl is currently registered on a variety of agricultural use sites (Table 3 and Appendix 1-2 of the BE), including: alfalfa, anise (fennel), apple, asparagus, avocado, bean (dry and succulent), beets, bermudagrass pasture, blueberry, broccoli, brussels sprouts, cabbage, carrot, cauliflower, celery, chicory, Chinese cabbage, collards, corn (field, pop-corn, seed and sweet corn), cotton, cucumber, eggplant, endive (escarole), garlic, grapefruit, horseradish, leafy green vegetables (beet tops, dandelion greens, kale, mustard greens, parsley, Swiss chard, and turnip greens), lemon, lentils, lettuce (head and leaf), melon, mint (peppermint and spearmint), nectarine, onion (green and dry bulb), orange, peach, peanut, pear, pea, pecan, pepper, pomegranate, potato, sorghum, soybean, spinach, sugar beet, summer squash, tangelo (tangerine), tobacco, tomato, tomatillo and wheat. In addition, there are several Special Local Needs or SLN registrations under FIFRA section 24(c), which authorizes state lead agencies to register additional uses of federally registered pesticides. SLN permits distribution and use only within the registering state) use sites, including broccoli rabe, Chinese broccoli, bean and soybean inter-planted with non-bearing fruit and nut trees, pumpkin, and sweet potato for California and radish for California and Florida. Methomyl is also registered for applications to sod farms (turf).

Table 3. Methomyl master use summary for agricultural uses with conventional application methods

Draft Table 3 Master
Uses Conventional.xls

Non-agricultural Uses

Non-agricultural outdoor uses for methomyl are limited to fly baits that can be used around livestock animal and poultry premises, commercial structures, and enclosed commercial dumpsters. The fly baits can be used as a perimeter scatter bait, placed in bait stations (hung at least 4 feet high), or mixed with water to form a paste which can be brushed onto walls, window sills, and support beams of outdoor livestock houses.

Consideration of Usage Data

Usage data describe how the pesticide has been applied to multiple use sites within a state, region, or the United States. In development of its BE, EPA reviewed usage data that documents the actual (field) applications of a pesticide, including information such as actual application rates and timing, and spatial distribution of applications across multiple sites (usually based on survey data). The key difference between use and usage is *use* refers to authorized applications under the label and *usage* refers to how it is actually applied on the landscape.

This Opinion considers the proposed action, specifically the registration review of methomyl according to its labeled uses. We recognize that the geographic areas authorized under the labels are intentionally broad to cover a variety of current and future, less predictable pest pressures and user needs throughout the action area (defined below) over the course of the 15-year duration of the proposed action. We also recognize that it is not realistic to assume the chemical will be used in every location in the action area where labeled uses allow, nor do we expect that the highest application rates and frequencies authorized under the label will occur in all these locations each year. Based on how the labels are currently written, we acknowledge the full range of uses and use sites allowed under the proposed registration review. While we agree methomyl will not be used everywhere, applied at the highest allowable frequency at each site, or applied at the highest application rates each time it is used (which would likely comprise more product than is currently manufactured or distributed), we also recognize that methomyl can be used anywhere the label allows, and at the highest rates and frequency specified for a given use. Similarly, we also recognize that, while knowledge of past usage patterns and locations may be helpful in providing context for where some uses are likely to occur, the past does not necessarily predict future pest pressures, management, or pesticide uses.

Mindful of the limitations associated with usage data, we utilize usage data to inform our analysis, but it is not dispositive in determining “effects of the action.” Because usage data represents historical patterns of how and where methomyl has been applied on the landscape, it is appropriately considered in determining “effects of the action,” which, under ESA section 7 regulations and Administrative Procedure Act standards, respectively, must be “reasonably certain to occur” and rationally based. At the same time, particularly where there are informational gaps, we apply usage data in this Opinion using our best professional judgment to make assumptions that are not only reasonable but are appropriately conservative for the species and critical habitat to determine whether EPA’s proposed action ensures against the likelihood of jeopardy of species or destruction and adverse modification of critical habitat. Although usage data is a portion of the best scientific and commercial data available, it is only one of many factors and points of data we consider in determining “effects of the action.”

Conservation Measures

This draft Opinion does not include any additional conservation measures in the proposed action (e.g., the registration) to address effects to listed species identified herein. Where conservation measures were already required for the use of methomyl products (e.g., buffers from aquatic areas), they were considered in our analyses. The Service, EPA, and technical registrant continue to discuss proposals that may be included as conservation measures to the proposed action prior to release of the final Opinion.

ACTION AREA

The action area is defined as all areas to be affected directly or indirectly by the federal action, and not merely the immediate area involved in the action (50 CFR 402.02). Consistent with the

ESA section 7 implementing regulations, in delineating the action area for methomyl, we evaluated the physical, chemical, and biotic effects of the proposed action on the environment that would not occur but for the proposed action and that are reasonably certain to occur. For the reasons mentioned below, the action area for this consultation is delineated by these effects to the environment and consists of the labeled uses within the entire United States and its territories.

Methomyl is a widely used chemical with multiple registered uses and formulations. To lawfully use methomyl, individuals are required to adhere to EPA's registered uses described on the label of products containing methomyl. Pesticide labels are legally enforceable, with all labels containing the following statement: "It is a violation of Federal law to use this product in a manner inconsistent with its labeling." Therefore, because only methomyl products registered under FIFRA may be lawfully used and registered methomyl products may be legally used only in the manner specified on EPA's label, any effects on the landscape from methomyl application would not occur but for EPA's registration review.

From EPA's BE, the action area was derived in ArcGIS 10.8 by combining the data layers representative of methomyl potential uses plus off-site transport. The overlap of methomyl potential use sites and potential off-site transport areas with individual species' ranges, critical habitat designations, as well as any additional species that the listed species depends upon, was then calculated. This analysis used spatial data of species' ranges and critical habitat designationss from the Services. In the conterminous United States (ConUS), agricultural potential use sites are represented using the USDA Crop Data Layer (CDL) (Appendix 1-5 of the BE). Other data sources are used to represent agricultural areas in states and US territories outside of ConUS, for which the CDL is not available (Appendix 1-6 of the BE). All species or critical habitats with some overlap of the use sites and off-site transport areas and their range or designated critical habitat, or with some overlap on species that the listed species depends on (Chapter 4 of the BE) are assessed in the MAGTool to make effects determinations for species and critical habitats. For EPA's final BE, several use data layers (UDLs) were updated, including parsing out alfalfa and other agricultural grasses (non-grazing area) from the pasture/rangeland (grazing areas).

The product labels for methomyl do not generally contain discreet geographic restrictions, except for certain generic buffer distances from sensitive areas. In the absence of geographic restrictions identified on the labels[3], and due to the variety of allowable agricultural uses for the chemical, the combination of uses on the label covers broad expanses and portions of every state and territory of the United States. Furthermore, the method(s) of application (e.g., by aircraft, ground, irrigation/chemigation, etc.) is expected to result in varying amounts of drift/transport of methomyl over and/or into terrestrial and aquatic habitats, as well as transport

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[3] We recognize that the various methomyl formulations are unlikely to be used evenly or consistently throughout the action area as defined. However, the labels describe all the allowable uses, and it is both conceivable and reasonable to assume the products, as labeled, could be used legally throughout the action area as described above. Pesticide labels are legally enforceable, and they all carry the following statement: "It is a violation of Federal law to use this product in a manner inconsistent with its labeling." Consequently, for the purposes of this consultation, we consider the labels to be the primary component of description of the proposed action that informs the extent of the action area (i.e., "the label is the law").

downstream/downcurrent via water bodies, such as wetlands, rivers, and lakes. Therefore, based on the labeled uses, the likelihood of transport from application sites, broad expanses of agricultural use sites, and indeterminant location of non-agricultural use sites, it is reasonable to assume one or more labeled uses could legally occur in any area of the United States and its territories throughout the duration of the proposed action. We recognize there may be some areas within the defined action area where applications would generally not occur. However, due to the uncertainty of future uses and expressed desire of the manufacturers to allow for addressing issues such as pesticide resistance and unforeseen pest or vector threats, the manufactures would like to reserve the right to allow usage per the current labels. Therefore, in considering usage information and commonly assumed use areas in our effects analyses, we assume, based upon our professional judgment and the extent of the label, that the action area will consist of the entire United States and its territories.

An evaluation of available information on past and present use and usage data further supports our conclusion that the action area encompasses the entirety of the United States and its territories. However, as explained in more detail in our analysis of species exposure and effects of the action, we identified some areas in which certain species are extremely unlikely to be exposed to generalized environmental effects arising from a specific registered methomyl use (i.e., the effect is discountable to the species), or alternatively, exposure would occur, but in such low levels that the effects to species from exposure are likely to be insignificant.

During past agency and stakeholder workshops and communication, we were occasionally asked to consider whether the Agencies should eliminate certain federal lands from the action area based on past or recent consultations where another action agency had already consulted on the use of the subject pesticide in their management plans or other actions. Examples include actions occurring on lands under the jurisdiction of the Service, the National Park Service, Bureau of Land Management, and U.S. Forest Service. A specific review of previous methomyl use on Service lands (e.g., National Wildlife Refuges) revealed no methomyl usage for the 10-year period of 2013 to 2023 (PUP Report 2023). Likewise, a review of past and recent consultations under section 7 of the ESA indicated that there has been no use of methomyl on federal lands. However, while informative, the queries of Service database information may not be definitive for other federal land management agencies (e.g., the Department of Defense). We are not aware of any agreements, plans, and/or other commitments by federal agencies related to the use and/or restriction of use of methomyl within their jurisdictions. For this reason, and because the labels allow use on federal lands, we determined it would be inappropriate to remove federal lands from the action area. Previous consultations involving methomyl use on federal lands are considered to be part of the environmental baseline.

Therefore, in light of multiple labeled uses for application on sites found throughout the United States and its territories, allowable methods of application that result in wide-spread transport of and exposure to methomyl products, the absence of geographic restrictions on the label, and available data on past and present use and usage, we conclude that generalized environmental effects are reasonably certain to occur and would not occur but for the registration in the entirety of the United States and its territories. As described in detail below, these environmental effects to the soil, air, and surface and ground waters, though generalized, are reasonably certain to occur on a nationwide basis and would not occur in these areas but for the FIFRA registration.

Methomyl can enter the environment via direct spray and spray drift onto soil, foliage, and/or water. It's vapor pressure (5.4×10^{-6} torr) and Henry's Law Constant (2.1×10^{-11} atm-m^3/mol) indicate that it has a low potential to volatilize, and long-range transport is most likely not a major pathway of concern.

Based on methomyl's aerobic soil metabolism and aerobic and anaerobic aquatic metabolism data, methomyl is not considered persistent[4] in the environment, with half-lives on the order of days to weeks (representative[5] half-life values range from 2.5 to 52 days). Under anaerobic conditions methomyl degradation is likely to be faster than under aerobic conditions (Smelt, et al. 1983), particularly in the presence of reduced iron (Bromilow, et al. 1986). It is stable to hydrolysis at lower pHs (neutral to acidic), but it degrades slowly in alkaline conditions (DT_{50} = 36-266 days). Hydrolysis half-lives indicate that methomyl is classified as persistent in aquatic and terrestrial environments where microbial activity is not present; however, microbial activity is expected in most natural environments.

Methomyl is classified as mobile (mobility can be measured as the organic carbon-water partition coefficient, or K_{FOC}; this number represents the ratio of the concentration of the chemical in soil/concentration of chemical substance in water. (K_{FOC}s range from 32-61 L/kg)[6] and has the potential to reach surface water through runoff and soil erosion. Overall, soil/sediment-water distribution coefficients increase with increasing percent of organic-carbon. Methomyl has the potential to reach groundwater especially in high-permeability soils with low organic-carbon content and/or the presence of shallow groundwater. The maximum depth of leaching in the terrestrial field dissipation studies is 30 inches. Predominantly methomyl will be present in the water column and to a lesser extent as bound to sediments. Based on measured octanol-water partition coefficients (K_{OW}s) and K_{FOC}s, exposure to sediment-dwelling organisms is likely to occur to a lesser extent as compared to organisms in water column. Low octanol/water partition coefficient also suggests that the chemical will have a low tendency to accumulate in aquatic and terrestrial organisms.

Air monitoring data collected from the 1960s through the 1980s and summarized by (Majewski and Capel 1995) do not indicate the presence of methomyl in the atmosphere, but more studies may be warranted. The authors' reviewed a single study which tested for methomyl in ambient air at three residential sites near an agricultural area in Salinas, California which were sampled during a high pesticide use month. Methomyl was not detected at any of the air monitoring sites (the level of detection was 35 nanograms per cubic meter).

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[4] Based on the Toxic Release Inventory classification system where half-lives greater than 60 days in water, soil, and sediment are considered persistent and half-life greater than 6 months are considered very persistent (US EPA 2012).

[5] Half-live values were recalculated using the North American Free Trade Agreement (NAFTA) guidance in estimating degradation kinetics (NAFTA 2012).

[6] Mobility was classified using the Food and Agriculture Organization (FAO) classification system (FAO, 2000) and supplemental sorption coefficients.

Major methomyl degradates include methomyl oxime (S-methyl-N-hydroxythioacetimidate), acetonitrile, acetamide, and CO_2. Methomyl oxime (S-methyl-N-hydroxythioacetimidate) was detected at a maximum of 44% in the alkaline hydrolysis study. Acetonitrile was detected at a maximum of 66%, 40% and 27% in the aqueous photolysis, soil photolysis and aerobic aquatic metabolism studies, respectively. Acetamide was detected at 14% in the aerobic aquatic metabolism study. CO_2 was detected at 22.5-75% in the aerobic soil, anaerobic soil, and aquatic metabolism studies. The only non-volatile degradate in the laboratory studies was methomyl oxime (S-methyl-N-hydroxythioacetimidate). It was present at high concentrations in the alkaline hydrolysis study but was only a minor degradate in the aerobic soil metabolism, anaerobic soil metabolism, photolysis, and aerobic aquatic metabolism studies.

There are data demonstrating the formation of methomyl sulfoxide during disinfection (chlorination) in water treatment (Girkin, R. 2002), although this compound was not found in any environmental fate studies.

None of the major methomyl degradates identified in the environmental fate studies is considered to be of toxicological concern based on the available data.

Overlap with Species Ranges and Critical Habitats

It is difficult to determine with precision where all labeled uses might occur over the duration of the proposed action. This is particularly difficult to predict beyond the next few years following completion of this consultation, as pest threats and pressures are difficult to foresee, and past use does not necessarily predict future use. The labels for this chemical:

(1) Allow for one or more uses among many land types in the United States and its territories.

(2) While the chemical is a restricted use pesticide, this specification does not prohibit all uses in any of these areas.

Thus, we are unable to eliminate overlap of any listed species[7] or designated critical habitats that occur within the action area, with the following exceptions[8]:

(1) listed species presumed extinct in the United States and its territories and their designated or proposed critical habitat;

(2) listed species presumed extirpated in the United States and its territories with no expectation of recolonization or plans for reintroduction over the duration of the proposed action; or

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[7] This Opinion does not consider foreign listed species, due to the extent of the action area as described in EPA's BE.

[8] It is our understanding that EPA recognizes reinitiation of consultation may be necessary if individuals of species presumed extinct or extirpated are discovered within the timeframe of the proposed action.

(3) listed species that occur only in captivity with no plans for reintroduction over the duration of the proposed action.

ANALYTICAL FRAMEWORK FOR JEOPARDY AND DESTRUCTION OR ADVERSE MODIFICATION DETERMINATIONS

Jeopardy Determination

Section 7(a)(2) of the ESA requires that federal agencies ensure that any action they authorize, fund, or carry out is not likely to jeopardize the continued existence of listed species. "Jeopardize the continued existence of" means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species (50 CFR § 402.02).

The jeopardy analysis in this Opinion considers whether the effects of the action, in the context of environmental baseline, status of the species, and cumulative effects, are expected to appreciably reduce the survival and recovery of the listed species. Thus, our analysis relies on four components: (1) the *Status of the Species*, which describes the condition of the species in its entirety, the factors responsible for that condition, and its survival and recovery needs; (2) the *Environmental Baseline*, which analyzes the condition of the listed species in the action area, without the consequences to the listed species caused by the proposed action; (3) the *Effects of the Action*, which includes all consequences to listed species that are reasonably certain to occur and would not occur but for the proposed action, including the consequences of other activities that are caused by the proposed action; and (4) the *Cumulative Effects*, which evaluates the effects of future, non-federal activities in the action area on the species.

For purposes of making the jeopardy determination, the Service: (1) reviews all the relevant information, (2) evaluates the current status of the species and environmental baseline, (3) evaluates the effects of the proposed action and cumulative effects, (4) adds the effects of the proposed action and cumulative effects to the environmental baseline, and, in light of the status of the species, determines if the proposed action is likely to jeopardize listed species.

Destruction or Adverse Modification Determination

Section 7(a)(2) of the ESA requires that federal agencies ensure that any action they authorize, fund, or carry out is not likely to destroy or to adversely modify designated critical habitat. A final rule revising the regulatory definition of "destruction or adverse modification" was published on August 27, 2019 (FR 44976). The final rule became effective on October 28, 2019 (84 FR 50333).

The destruction or adverse modification analysis in this Opinion relies on four components: (1) the *Status of Critical Habitat*, which describes the range-wide condition of the critical habitat as a whole in terms of the key components (i.e., essential habitat features, physical and biological features, or primary constituent elements) that provide for the conservation of the listed species, the factors responsible for that condition, and the intended value of the critical habitat overall for the conservation/recovery of the listed species; (2) the *Environmental Baseline*, which analyzes the condition of the designated critical habitat in the action area, without the consequences to the designated critical habitat caused by the proposed action; (3) the *Effects of the Action*, which includes all consequences to the critical habitat that are reasonably certain to occur and would not occur but for the proposed action, including the consequences of other activities that are caused by the proposed action; and (4) *Cumulative Effects*, which evaluate the effects of future non-federal activities that are reasonably certain to occur in the action area on the key components of critical habitat that provide for the conservation of the listed species and how those impacts are likely to influence the conservation value of the affected critical habitat.

For purposes of making the destruction or adverse modification determination, the Service: (1) reviews all relevant information, (2) evaluates the current status of the critical habitat and environmental baseline, (3) evaluates the effects of the proposed action and cumulative effects, (4) add the effects of the action and cumulative effects to the environmental baseline and, in light of the status of the critical habitat, determines if the proposed action is likely to result in the destruction or adverse modification of critical habitat.

STATUS OF THE SPECIES AND CRITICAL HABITAT

In their BE, EPA identified numerous listed, proposed and candidate species and proposed and designated critical habitats that may be affected by the proposed action. Species addressed in this Opinion are listed in Table 4 (animal species) and Table 5 (plant species). Species that were included in the BE but have been removed from this Opinion because the species are not currently listed are included in Appendix A of this Opinion. The detailed status of each listed, proposed, and candidate species and their proposed or designated critical habitat is provided in Appendix B. Some additional species have been listed and critical habitats have been designated for which we do not have EPA's determinations or the other information needed for our analyses. We intend to work with EPA to address them in our final Opinion.

Table 4. Listed, proposed, and candidate animal species and proposed and designated critical habitats addressed in this Opinion included in the BE for methomyl.[9]

Draft Table
4_Animals species (BE

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[9] For determinations and conclusions in Tables 4 and 5: LAA = "may affect, likely to adversely affect;" NLAA = "may affect, not likely to adversely affect;" NE = "no effect;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

Table 5. Listed, proposed, and candidate plant species and proposed and designated critical habitats addressed in this Opinion included in the BE for methomyl.

Draft Table 5_Plant species (BE).xlsx

The listed entities in Table 6 are designated non-essential experimental populations. They were included in EPA's BE, with all populations except one[10] given a "likely to adversely affect" determination by EPA. These populations were designated to support the recovery of listed species in taxa groups including birds, bivalves, fishes, insects, mammals, and snails. For the Opinion, we are not providing separate conclusions for individual experimental populations, as these were generally within the range of the species and included in the information about the species used in our assessments. They are therefore covered by our analysis. Federal agencies are not required to consult on non-essential experimental populations outside of national wildlife refuges or national parks. In this case, EPA would only be required to confer on non-essential experimental populations if the proposed action was likely to jeopardize the species. Thus, while EPA was not required to confer on these non-essential experimental populations, they provided determinations for them in their BE.

Table 6. Listed entities comprised of experimental populations (all are non-essential populations).

DRAFT Table 6 EXPN Populations.xlsx

ENVIRONMENTAL BASELINE

The environmental baseline is defined as "the condition of the listed species or its designated critical habitat in the action area, without the consequences to the listed species or critical habitat caused by the Action." It "includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process. The impacts to listed species or designated critical habitat from Federal agency activities or existing Federal agency facilities that are not within the agency's discretion to modify are part of the environmental baseline" (50 CFR § 402.02, as revised May 6, 2024).

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[10] The BE indicated a "may affect, not likely to adversely affect" determination for the grizzly bear (entity ID 1302); this listed entity is addressed in the *Concurrence* section, Appendix B of this Opinion.

Because this consultation addresses a large geographic area and the distribution of species within the action area is widespread, this Opinion will consider the environmental baseline at a broad scale. Many of the ESA-listed species and their critical habitats are exposed to multiple stressors comprising the past and present impacts of actions and activities that are described below. The environmental baseline in this Opinion focuses primarily on the status and trends of the ecosystems in which these species and their critical habitats occur in the United States and the factors that contribute to the current status for ESA-listed species and their resources. We first explore factors that affected listing decisions over the last several decades, then describe factors that affect the environmental baseline for listed species and designated critical habitats, including pesticide use, land use change, invasive species, pollution, harvesting, water-related issues, climate change, and several others.

In Table 7 (column 2), we present threats that contributed to listings for 877 ESA-listed species identified through Federal Register documents up to August 1994 (Czech, Krausman and Devers 2000). In Table 7 (column 3), we also present the factors associated with 143 ESA listing decisions (threatened and endangered) from February 2011 to October 2014 (Smith-Hicks and Morrison 2021). In both assessments, the most frequently referenced threats were: non-native species, urbanization/roads, agriculture, and loss of genetic viability/small population sizes. Before 1994, some species were listed due to threats that were not referenced in the 2011-2014 rules (e.g., aquifer depletion/wetland filling, native species competition, and vandalism). In the 2011-2014 rules, several new threats were presented (i.e., commercial fishing, climate change, and pesticides/herbicides). Some species may be affected by multiple stressors at the same time. Of particular interest is that several factors (e.g., pesticides, agriculture, fire suppression and related activities, urbanization, and water diversions) were influential to species' listings across both time periods (before 1994 and between 2011-2014).

Table 7. Threats identified for ESA-listed species from rules before 1994 (column 2) and between February 2011-October 2014 (column 3). Modified from (Czech, Krausman and Devers 2000) and (Smith-Hicks and Morrison 2021).

Threat	Number (%) of Species Listed by Threat (Czech, Krausman, & Devers, 2000)	Number (%) of Species Listed by Threat (Smith-Hicks & Morrison, 2021)
Non-native species	305 (35)	76 (53)
Urbanization	275 (31)	77 (54) (combined with Roads in "Land conversion")
Agriculture	224 (26)	55 (38)

Threat	**Number (%) of Species Listed by Threat (Czech, Krausman, & Devers, 2000)**	**Number (%) of Species Listed by Threat (Smith-Hicks & Morrison, 2021)**
Recreation	186 (21)	38 (27) (combined with Industry/Military in "Competing uses")
Ranching	182 (21)	49 (34) (combined with Fire suppression in "Modified disturbance regimes")
Reservoir and water diversions	161 (18)	52 (36)
Fire suppression	144 (16)	49 (34) (combined with Ranching in "Modified disturbance regimes")
Pollution	144 (16)	30 (21)
Mining/Oil & gas	140 (16)	47 (33) (combined with Logging in "Resource use")
Industry/military activities	131 (15)	38 (27) (combined with Recreation in "Competing uses")
Harvest	120 (14)	18 (13)
Logging	109 (12)	47 (33) (combined with Mining/Oil and gas in "Resource use")

Threat	**Number (%) of Species Listed by Threat** **(Czech, Krausman, & Devers, 2000)**	**Number (%) of Species Listed by Threat** **(Smith-Hicks & Morrison, 2021)**
Roads	94 (11)	77 (54) (combined with Urbanization in "Land conversion")
Loss of genetic viability	92 (10)	97 (68)
Aquifer depletion/wetland filling	77 (9)	N/A
Native species competition	77 (9)	N/A
Disease	19 (2)	31 (22)
Vandalism	12 (1)	N/A
Commercial fishing	N/A	3 (2)
Climate change	N/A	56 (39)
Pesticides/Herbicides	N/A	22 (15)
Unknown or Other	N/A	8 (6)

Land Use and Land Cover Change

A primary factor negatively affecting imperiled species are changes to their habitat. Many habitat modifications have occurred in the United States throughout human history, the earliest of which likely included the use of fire to encourage or discourage the growth of certain plant communities. The types and extent of habitat changes have increased through time, with much of the land in the United States now being used for agriculture, forestry, urban and industrial development, and mining. Each of these land uses affect species and habitats differently. The land use categories that most affect species and habitat long-term are agriculture and urban/industrial development.

Over the last 300 years, forests in the eastern United States were reduced by at least half due to land use change for agriculture, urbanization, and infrastructure development. Intensive, large-scale land use changes began during European settlement and continued rapidly as settlers moved west, exploiting the land for tobacco and lumber for export (Keeney and Kemp 2002). The United States Congress gave away land in the West to encourage settlement through the Homestead Act, and development further increased as transportation across the country became easier with the invention and expansion of railroads after the 1830s. Many prairie habitats (tall, mixed, and short grass) were nearly eliminated by agricultural expansion. Between 1938 and 1992, urban areas expanded by 140%, wetlands decreased, and agricultural land uses (e.g., cropland and hay) decreased nationwide by 18% with higher decreases in the East. Forestland and grassland increased, primarily due to agricultural abandonment (Sohl, et al. 2016). Between the early 1900s and early 2000s, the area of forest cover in the United States was relatively stable (Masek, et al. 2011), though reforested areas may not provide the same quality of habitat as unharvested, old-growth forests do for ESA-listed species (Sutherland, Gergel and Bennett 2016). For example, marbled murrelets use old-growth forests that take 100-200 years to recover with necessary nesting habitat structures (USFWS 1997), and if these forests are removed, they may not recover into the same forest structure as was present before deforestation took place. In many cases, abandoned areas succeed into different communities from the ones that occurred before the land was converted to agriculture.

Agriculture

Agriculture (e.g., croplands and animal operations) is a principal industry in the United States, accounting for over 50% of the country’s land uses (cropland, pasture and range, forested grazelands). As of 2021, there were over 2 million crop and livestock farms (a decrease of nearly 7,000 from 2020) across approximately 895,300,000 acres of land in the United States (NASS 2022). Most grasslands in the United States are plowed and planted for crops for human consumption, livestock grazing, and more recently, biofuel production (Mitchell, et al. 2010). Crop production is concentrated in the Midwest and California (Figure 1), but it occurs across the country in every state (USDA, United States Summary and State Data 2017).

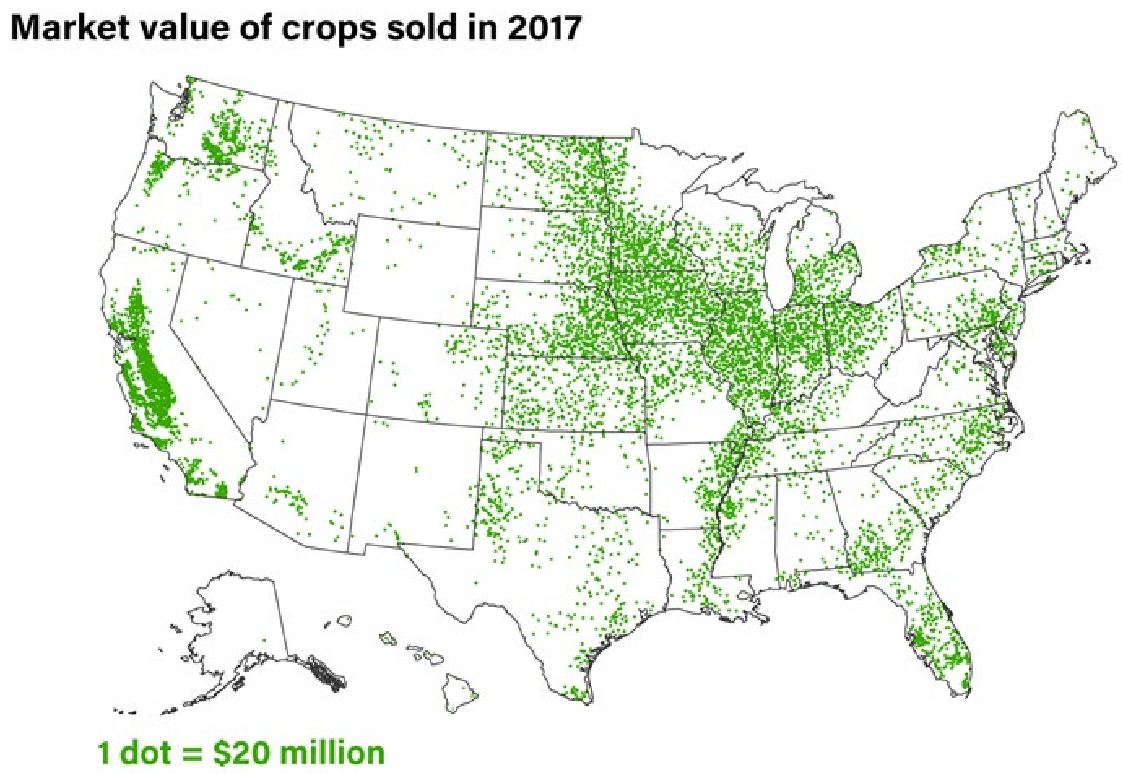

Figure 1. Market value of United States crops sold in 2017; data and figure from (USDA 2017).

Between 2008-2016, croplands expanded by over 10 million acres across the continental United States, with over 1 million acres converted per year. Simultaneously, 3.52 million acres of cropland were converted to non-cropland uses, including abandonment (Lark, et al. 2020) (Figure 2). Land use change is non-linear and when one area is converted from a natural area to agriculture, another may be allowed to succeed into a novel natural area after abandonment.

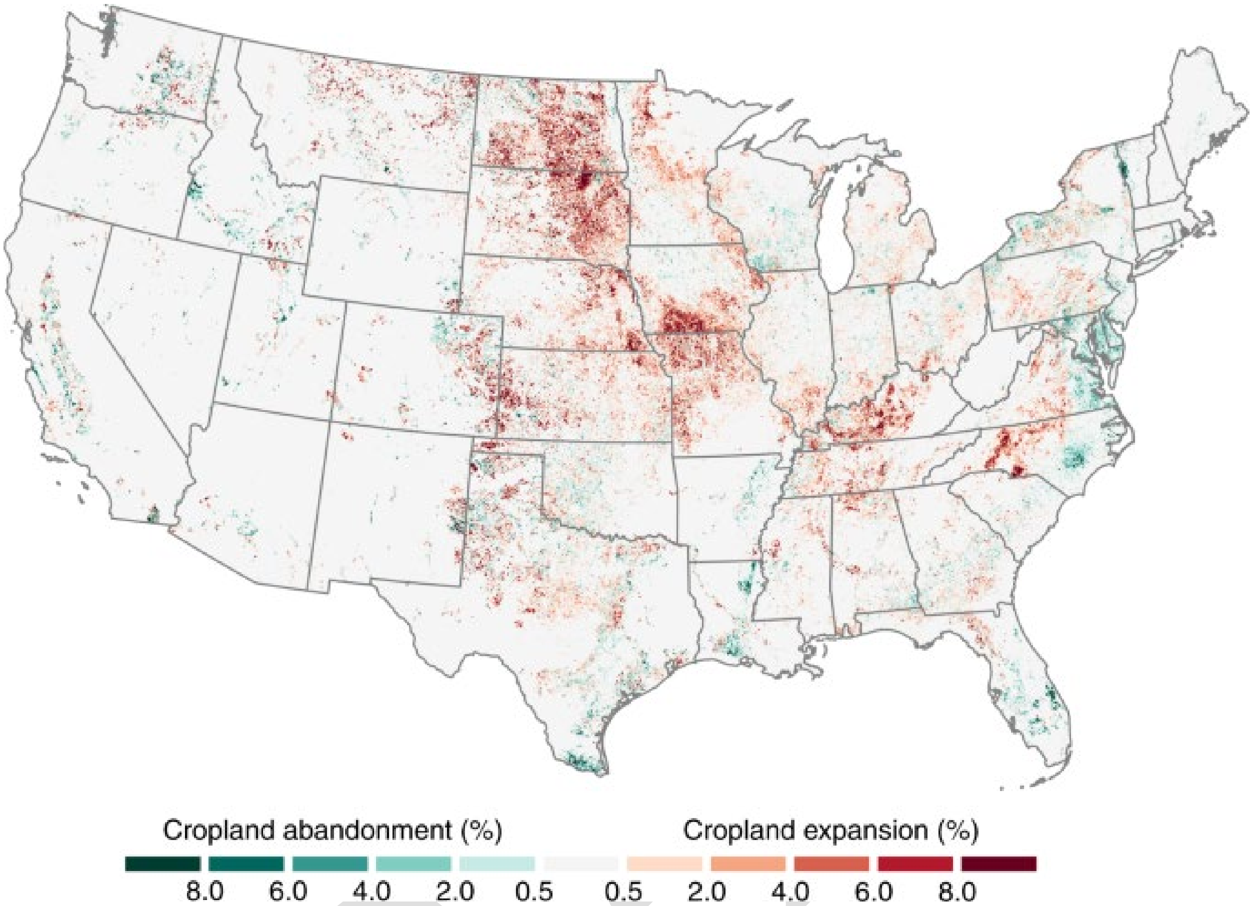

Figure 2. Cropland conversions between 2008-2016 in the continental United States, including abandonment and expansion (Figure 1 from (Lark, et al. 2020)).

Crop production can lead to pesticides leaching into groundwater and entering streams from surface water runoff (Spence, et al. 1996, Rao and Hornsby 2001). Several pesticides were detected in small streams and sloughs within agricultural and urban sites tested within Puget Sound (Bortleson and Davis 1997). In periodic reconnaissance studies of streams in nine Midwestern states, the U. S. Geological Survey documented that large quantities of herbicides and their degradate products were flushed into streams during post-application run-off (Scribner, et al. 2003). For more information about effects of pesticides, please see the *Use of Pesticides* section below.

Large animal husbandry operations are common in the Midwest and throughout the eastern U.S. (Figure 3). In 2019, the cattle inventory in the United States was approximately 95 million head. Texas has the most cattle (13%) in the United States, followed by Nebraska and Kansas. Thirty-one states have more than 1 million head of cattle, fourteen have more than 2 million, and nine have more than 3 million head of cattle (based on USDA NASS data as cited in (Cook 2019)). Other smaller operations raise horses, pigs, sheep, geese and ducks, dairy goats, rabbits, and exotic animals (e.g., llamas, emus, alpacas, ostriches). Many animal operations require grasslands for grazing and/or pasture farming (i.e., rangelands, pasturelands, and others), which occur in a large portion of the United States. Rangelands are managed as a natural ecosystem with mostly native grassy vegetation, while pasturelands are grazing lands used to permanently produce forage species, primarily for grazing animals (GLTI 1997). In the East, grasslands are mostly seeded pasturelands and, in the West, grasslands are mostly rangelands. Seeded pasturelands often receive more fertilizer and herbicides to control unwanted species than rangelands (Mitchell, et al. 2010). As of 2018, some rangelands in the West were in relatively good condition (i.e., Great Plains) and others were in concerning conditions (i.e., Intermountain, Southwest Regions) from invasion of weedy plants, shrubs, and non-natives (i.e., bromes, mesquite); erosion; and aridity and drought (NRCS 2018a). As of 2018, 6% of non-federal lands are pastureland, most of which is in the South Central, Midwest, and Southeast regions of the United States (NRCS 2018b).

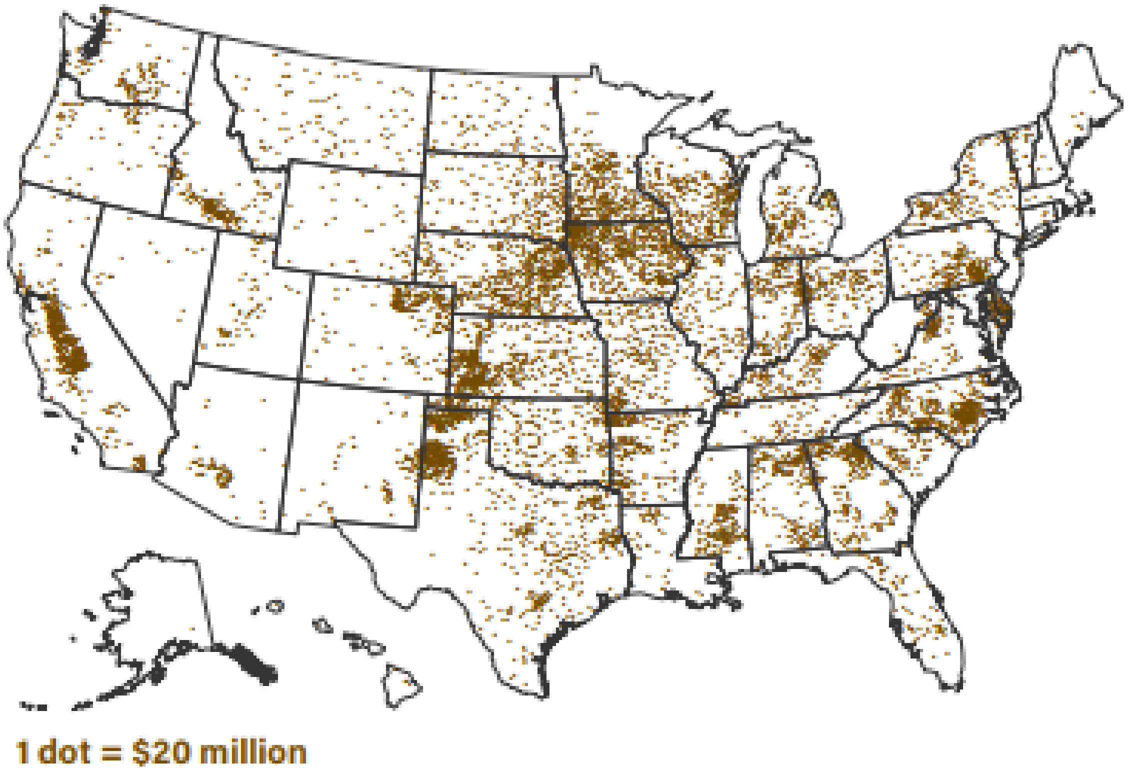

Figure 3. Market value of United States livestock, dairy, poultry, and their products sold in 2017; data and figure from (USDA, United States Summary and State Data 2017).

Livestock grazing has been important to the United States agriculture system for centuries. In some areas, intense grazing resulted in a general decline in range conditions; conflicts among livestock owners due to limited resource availability; removal of highly flammable fuels and reduction in ground fires that limited tree seedling establishment; uncontrolled fires caused by purposeful fire setting by livestock owners; establishment of invasive, non-native vegetation; and increase in siltation of water bodies (Oliver, Irwin and Knapp 1994). As a result, the Bureau of Land Management began regulating grazing on public rangelands in the 1930s. Asian grasses were introduced as stabilizing vegetation for the erosion caused by overgrazing and other practices. The reduction in the number of sheep and localized declines in cattle grazing pressure allowed recovery of some rangeland, including forests (Oliver, Irwin and Knapp 1994). By the

1960s and 1970s, legislation allowed for monitoring, improvements, and better stewardship of rangeland (including those in National Forests). Despite these efforts, over 70% of federal land (e.g., Bureau of Land Management, U.S. Forest Service) was grazed by cattle and sheep in the western Unites States by 1970 (CAST 1974).

Agricultural grasslands, including rangelands and pasturelands, provide many ecosystem services to wildlife. For example, agricultural lands have less impervious land cover than urban or industrial lands (Nowak and Greenfield 2010). Low-intensity agricultural lands provide food resources, shelter, and environmental heterogeneity that help some species to thrive. In contrast, agriculture is the leading cause of deforestation (Benayas and Bullock 2012) and is responsible for 10% of anthropic greenhouse gas emissions in the United States (USEPA 2021). Agriculture has contributed to the loss of side-channel areas, loss of native and riparian vegetation, degradation of water quality, and introduction of contaminants (Hamilton and Helsel 1995). Effects from livestock grazing can be considerable if management practices are not sufficient to protect habitat functions (Wissmar, et al. 1994, Belsky, Matzke and Uselman 1999). In overgrazed areas, native understory grasses are eliminated, tree seeds establish and are not consumed by grazers, and dense tree seedling areas further succeed in the absence of fire (Madany and West 1983, Franklin, et al. 2008), changing the vegetation composition of the habitat over time. Livestock trampling damages fragile moss and lichen layers (i.e., biocrust) that provide nutrients to the soil, protect the soil against erosion, support native grasses, and limit colonization by non-native invasive vegetation (e.g., cheatgrass) (Finger-Higgins, et al. 2022).

Agriculture is the leading cause of water quality concerns in the United States (Keeney and Kemp 2002). Water quality can be affected by increases in temperature and sediment from clearing shaded riparian areas along waterways and solar heating of water flowing across fields. Irrigation systems often result in warmer water temperatures in canals and streams also. In addition to effects on or adjacent to agricultural lands, effects to water quality may extend far downstream of agriculture activities through runoff. For example, livestock production often degrades water quality through the addition of excess nutrients from animal manures and agricultural fertilizer, which can contribute to excessive growth of aquatic plants, harmful algal blooms, reduced levels of dissolved oxygen, and adverse effects to fish (Embrey and Inkpen 1998, USEPA 2006) and other aquatic organisms. Additional impacts to water quality may result from improper spreading of manure and increased surface runoff from overgrazed pasture and/or other areas in which large numbers of animals are confined (Rau 2015).

Other impacts result from the maintenance of grazing lands. Fencing can provide important environmental benefits such as keeping cattle out of sensitive areas, but construction, reconstruction, and maintenance activities may require transport and staging of materials, digging of holes, and stringing or re-stringing wires or fences. Chemically treated-wood posts are often used at corners with braces and interspersed metal posts, wooden posts, or live trees. On flat terrain, power equipment may be used to auger holes and construct fencing. On steep terrain, hand tools and chain saws become more common. Rock cribs are often used when crossing areas of bedrock. Each of these activities can affect sensitive species and habitats through noise, human disturbance soil compaction, among others.

Various levels of government have attempted to begin correcting some of the past impacts on the country's ecosystems from agricultural operations. In 1970, the EPA took over implementation of FIFRA to regulate the registration and use of chemical pesticides, although some authors note challenges associated with its implementation. Additionally, state and federal programs were organized to aid landowners in voluntarily managing their properties to improve water and habitat quality (Edge 2001). The 2002 farm bill drastically increased funds for conservation and created the voluntary Conservation Security Program (Keeney and Kemp 2002), which provided funds to producers for conservation actions. Though revised a few times since its establishment, the Conservation Stewardship Program (formerly, Conservation Security Program) has been reauthorized with each new farm bill (Stubbs 2023).

Forestry Activities

At the beginning of European settlement in 1630, an estimated 423 million hectares (46%) of what would become the United States was forest lands. Many forest lands were converted to other uses such as agricultural and urban uses over the next several hundred years. From 1850 to 1997, forest land remained relatively stable across the country and by 2012, forests comprised 309 million hectares (USDA 2014). Reserved forest land, state and federal parks, and wilderness areas, has doubled since 1953 and now stands at 7% of all forest land in the United States (not including conservation easements, areas protected by nongovernmental organizations, and most urban and community parks and reserves). Significant additions to federal forest reserves occurred after the passage of the Wilderness Act in 1964 (USFS 2001). According to the U.S. Forest Service, the most acreage of forest lands occurs in the western United States, followed by large areas in the southern and northern parts of the country.

Intensive forest management generally results in adverse effects such as loss of older forest habitats and habitat structures, increased fragmentation of forest age classes, loss of large contiguous and interior forest habitats, decreased water quality, degradation of riparian and aquatic habitats, and increased displacement of individual species members. Intensive forest management on most private lands generally maintain these lands in an early seral stage (e.g., 40 to 50 years of age) with relatively few structures such as snags, down logs, large trees, variable vertical layers, and endemic levels of forest "pests" and "diseases," when compared to what was historically present prior to intensive management.

Timber Harvest

Forested areas that were considered unsuitable for agriculture were frequently managed for timber harvest. Pioneers used river systems to transport logs and other goods. Trees were felled directly into streams, rivers, and saltwater and floated to their destinations, or pulled to streams and trapped behind splash dams, which were dynamited or pulled away, causing logs to sluice downstream. Following World War II, truck road systems replaced railroads, but smaller streams continued to be used as transportation corridors. After 1930, the introduction of motorized trucks and chainsaws allowed for substantial increases in harvest. Fueled by the demand for new housing and development after World War II, harvest increased dramatically. Much of the lowlands initially harvested for timber were subsequently cleared for agriculture and residential development. While timber harvest continues to occur across the country, conversion of forest lands to other uses have become more common as the human population has grown.

Timber harvest changes the forest composition and can change forest ecosystem functions. Before timber harvest began, forest composition included many age classes, diverse species, and various canopy levels. Timber harvest initially focused on large-diameter trees and, secondarily, small-diameter trees, ultimately reducing the number of large-diameter trees in forests and slowing recruitment (Sedell, Leone and Duval 1991, USFS 2003). In particular, old-growth forests have declined on federal and non-federal lands across the United States, and they take 150+ years to grow. Once old-growth forests are disturbed, they may not succeed or recover with the same characteristics that they had before the disturbance (i.e., they may have a different species composition) (Spies 2004). Many species rely on characteristics of old-growth forests that are not found or are less common in other habitat types (i.e., tree snags). In addition to providing unique habitat, temperate coastal rainforests collect moisture from fog, which helps provide water to these ecosystems without rainfall. Significant reductions in large trees may result in less moisture retention, affecting future runoff and/or precipitation patterns (Dawson 1998).

In addition to forest effects, timber harvest and associated activities, such as road construction and skidding, can increase sediment delivery to streams, clogging substrate interstices and decreasing stream channel stability and formation. Harvest in riparian areas decreases woody debris recruitment and negatively affects runoff patterns. Runoff timing and magnitude can change to deliver more water to streams in a shorter period, which causes increased stream energy and scouring and decreased base flows during summer months. Stream temperatures may rise with decreases in the forest canopy and riparian zone shading. Loss of large trees also increases erosion and simplifies stream channels (Quigley and Arbelbide 1997).

Improvements in forestry methodologies have reduced some effects from these practices. In some areas, harvest units have been restricted in size, and greater consideration has been given to the health and appearance of forest landscapes and the biotic communities that depend on them. In some cases, equipment is used and/or engineered in ways to minimize soil disturbance and other habitat impacts. In other cases, however, the methods used may result in increased soil disturbance and extreme fire hazards (e.g., machine piling and burning, accumulation of dead slash from thinning activities, etc.) (Oliver, Irwin and Knapp 1994).

Fire Suppression

Under historical fire regimes, natural disturbance from forest fires resulted in a mosaic of diverse habitats. Before European settlement in the United States, both natural and human-initiated fires are believed to have affected forests. Fire is a necessary phenomenon for many ecosystems; many species rely on fire, like jack pines whose cones only open when heated during a fire and Douglas fir seedlings rely on openings in the canopy made by forest fires to grow (Cooper 1961). In addition to facilitating germination of some pine species and making room for others to grow into the canopy of a forest, fires release nutrients back into the soil, maintain grassland and other early successional habitats that are otherwise overtaken by forests, and diversify landscapes more broadly (Knapp, Estes and Skinner 2009). In some lowland areas, fires were frequent and not highly destructive, primarily burning off revegetation. At higher elevations and in cooler areas, fires were less frequent and highly destructive.

Starting in the late 1880s, fire suppression was used to protect human-dominated areas and it became a priority of the U.S. Forest Service to suppress all fires in 1905. Forest control and suppression since the early 1900s changed the composition of many forests across the United States. Historically, burned areas were maintained as early successional vegetation through grazing or were left to develop into dense stands with different compositions than was previously present. Many fire-dependent pine species were outcompeted by hardwoods (e.g., oaks, maples, yellow poplar) that do not need fire to reproduce and are otherwise restricted to wetter environments (Keane, et al. 2008). The environmental integrity of forests changed and denser forest stands may be more susceptible to disease and pests (Oliver, Irwin and Knapp 1994). Fire suppression led to a buildup of forest fuels, which increased the likelihood of large, intense forest fires in some areas. Large fires can cause longer-lasting damage than small fires because their heat effects run deeper into the soil and they can create larger burn areas (Keane, et al. 2008).

Although fire suppression was viewed as necessary to protect resources and private property, some advocated the use of prescribed fire to reduce fuels and protect stands against damaging fires. In the 1960s, the National Park Service recognized that fire was an important natural process and began letting naturally ignited fires run their course under prescribed conditions. The Forest Service began allowing natural fires to burn in wilderness areas in 1974. Other land management agencies (e.g., U.S. Fish and Wildlife Service, Bureau of Land Management, Bureau of Indian Affairs) began implementing fire management, as opposed to fire control, in the 1990s and 2000s (van Wagtendonk 2007).The use of prescribed fire in certain environments was encouraged, with certain precautionary measures. Although scientists recognized the value of prescribed burning as one of many tools to help return landscapes to natural conditions, some managers have been slow to embrace prescribed burning partially due to liability. There are other constraints upon prescribed burning including short-term expenses and air-quality regulations.

Forest Diseases and Pests

Forest diseases and pests were present in forests before European settlement, including fungal pathogens, defoliating insects, among others. Many diseases and pests were transported unintentionally to the United States as world travel became more common. Invasive insects and plant pathogens can change forest composition and structure if they only damage a subset of the plants in the habitat (Poland, et al. 2021). By the mid-1900s, several defoliating insects were documented across the United States (e.g., tussock moths, pine butterflies, bark beetles, pine beetles) that kill trees, reduce their growth, and increase their susceptibility to other damage from insects or disease (Kulman 1971). Starting in the 1930s, surveys and control were used to combat pests. Pest control included selective harvesting or salvage harvest to remove infested trees, pesticide use (e.g., ethylene dibromide, dichlorodiphenyltrichloroethane (DDT), and other insecticides), and removal of host plants (e.g., currant [*Ribes* spp.], host of white pine blister rust). Between 1860-2006, about 2.5 new non-native forest insects were detected in the continental United States each year. By 2010, there were an estimated 450 non-native insects and 16 new pathogens in our forests and urban trees, and at least 14% of them caused notable tree damage (Aukema, et al. 2010). In addition, fungal pathogens, oomycetes, and parasitic plants can devastate forests and change their structure and composition (Cobb and Metz 2017). Forests that have been affected by defoliating insects and/or pathogens are more susceptible to other threats like drought, fire, and effects of climate change (Kliejunas, et al. 2008).

Since the 1960s, integrated pest management has been used to control insect outbreaks. With integrated pest management, several pest-control alternatives are rated against cost/benefit analyses, alternative strategies, ecological considerations, and other concerns to determine the best recourse against the target pest(s). Examples of integrated pest management alternatives include favoring resistant stand structures and/or species in thinning and planting activities, fire prescription, selective use of pesticides, and salvage logging (Oliver, Irwin and Knapp 1994).

Urbanization

In general, urban land acreage quadrupled from 1945 to 2007 with an estimated 61 million acres in 2007 (Nickerson, et al. 2011). By 2012, USDA estimated that 70 million acres of the United States (3% of total land area) were urbanized. Urban land area more than doubled the population growth rate between 1945 and 2012, and between 1982 and 2012, the increase in developed land acreage was primarily driven by conversion of forest and cropland. (Bigelow and Borchers 2017). Between 2001 and 2016, the most persistent and permanent land use change in the continental United States was development (5.6 of the total land area), most of which occurred between 2001-2006 (Homer, et al. 2020). Figure 4 depicts the 2020 human population density by county in the United States and serves as a coarse representation of urbanization. Between 2010-2020, the United States human population grew by over 22 million people, with a total population in the 2020 Census of 331,449,281 people (USCB 2021). In general, urbanization (including impervious land cover, manufacturing and waste, housing densities, and contributions to greenhouse gas emissions) concentrates effects of water, land, and mineral use; increases the pollutant load in water and on the land; increases the likelihood of noise and air pollution; contributes to degradation of ecosystems and habitat for fish, wildlife and plants; lessens biodiversity; and contributes to changes in climate at varying scales.

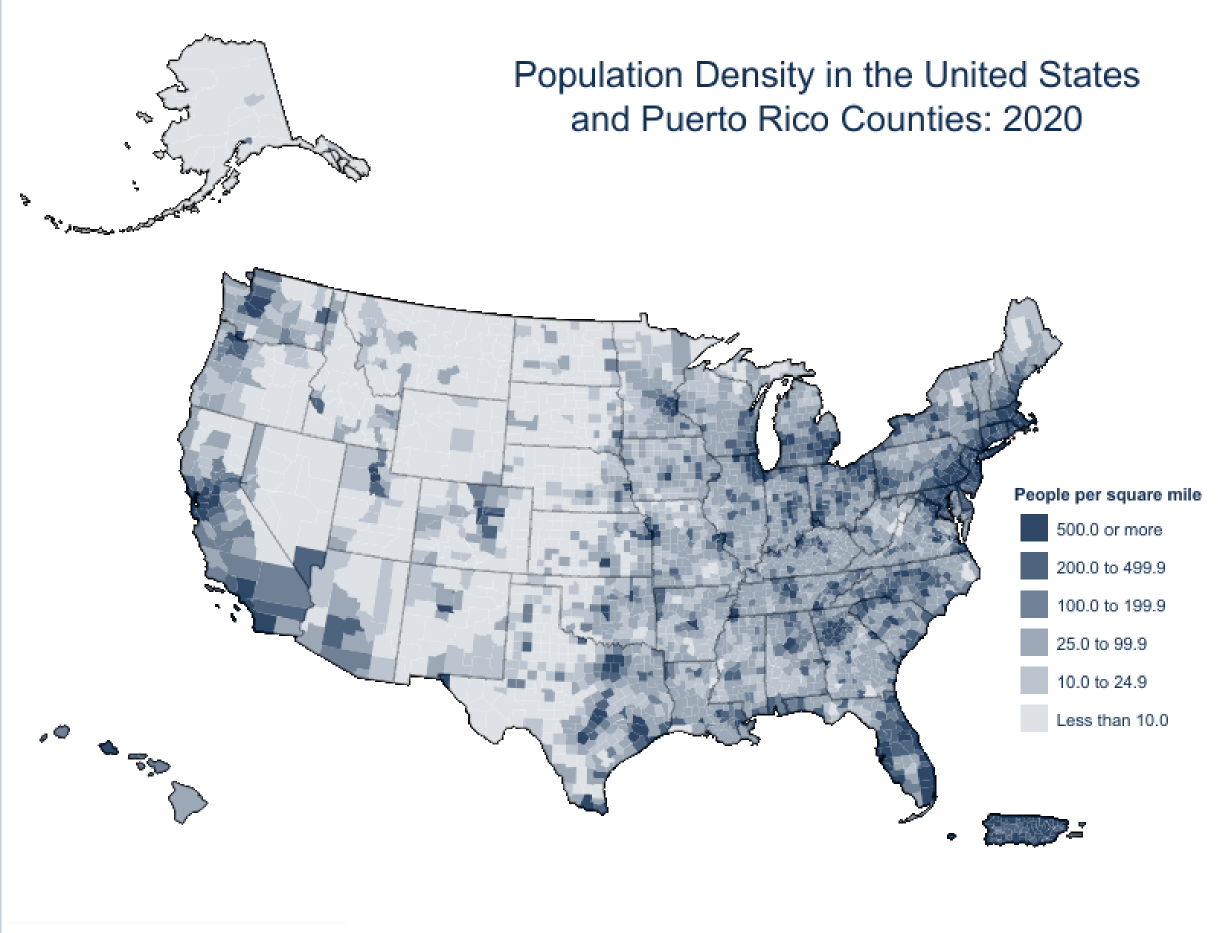

Figure 4. United States population density by county (USCB 2021).

Land uses in urban and suburban areas are cited as the primary cause of declining environmental conditions in the United States (Flather, Knowles and Kendall 1998) and other areas of the world (Houghton 1994). Urban and suburban development often includes construction of roads, railroads, associated rights-of-way (ROWs) and associated clearing of vegetation and other habitat features. These activities, as well as installation of below grade utility lines, pipelines, transmission lines and other infrastructure, can change terrestrial and riparian habitats and simplify and channelize streams, thereby reducing connectivity of surface water and groundwater. Historically, stream materials (e.g., sand, gravel, and cobbles) were often used as fill, and excess excavation materials were pushed over the road bank, where they frequently entered streams. Riparian vegetation and stream banks were damaged using heavy equipment adjacent to and in streams. Side channels were often cutoff or eliminated, and stream channels were confined, resulting in increased bank erosion in certain areas. Lack of adequate drainage led to saturation of roadside soils. In many parts of the United States, road and ROW siting, construction, and maintenance practices have not changed significantly through time and thus continue to contribute to the decline of ecosystem function for fish, wildlife, and plants. Constriction of floodplains resulted in increased flooding (Palmisano, Ellis and Kaczynski 2003), which continues today in some areas. Construction, maintenance, and use of urban and suburban areas can also result in loss or degradation of riparian and wetland areas, degradation and fragmentation of terrestrial plant and animal habitats, sedimentation, erosion and slope hazards, reduction of species' passage, dispersal, or migration , and increased strike hazards to many classes of animals. Activities that involve land disturbance increase the risk of erosion and, therefore have the potential to affect the quantity of sediment that reaches waterways. Excessive sediment reduces stream depth, leads to increases in water temperatures and reductions in dissolved oxygen content (Ringler and Hall 1975, Henley, et al. 2000).

Most land areas covered by natural vegetation are highly porous and have limited sheet flow; precipitation falling on these landscapes infiltrates the soil, is transpired by the vegetative cover, or evaporates. The transformation of land into a mosaic of urban and suburban land uses has increased the area of impervious surfaces (e.g., roads, rooftops, parking lots, driveways, sidewalks). Precipitation that would normally infiltrate soils in forests, grasslands and wetlands falls on and flows over impervious surfaces and runs off the land. Runoff is channeled into storm sewers and released directly into surface waters (e.g., rivers and streams), which changes the magnitude and variability of water velocity and volume in those receiving waters. Runoff also can transport pollutants into waterways and across landscapes.

Impervious surfaces associated with residential and urban development create one of the most lasting impacts to stream systems. The amount of new impervious surfaces increased significantly in recent history, and this trend will likely continue in the future. There is a strong relationship between the amount of forest cover, level of impervious and compacted surfaces, and degradation of aquatic systems (Klein 1979, Booth, Hartley and Jackson 2002). Intensive development leads to losses of forest cover, increases in impervious surfaces, and changes to hydrology (e.g., increased peak flows, increased flow duration, reduced base flows, decreased evapotranspiration and groundwater infiltration) and these environmental changes can be detected when impervious surface in the watershed is as low as 5 to 10% (Booth, Hartley and Jackson 2002, May, et al. 1997). Some environmental changes, like increased peak flows and flow duration, often require engineering channels to address flooding, erosion, and sediment-transport concerns. Impervious surfaces also increase stormwater runoff, which causes many contaminant and pollution concerns (see the *Use of Pesticides* and *Pollution* sections below).

Additional water-quality concerns related to urban and suburban development include stormwater runoff, adequate sewage treatment and disposal, transport of contaminants to streams by storm runoff, and preservation of stream corridors. Human-dominated landscapes influence water availability, which has been and will continue to be a major, long-term issue in many areas. It is now widely recognized that ground-water withdrawals can deplete streamflows (Morgan and Jones 1999), and one of the increasing demands for surface water is the need to maintain instream flows for fish and other aquatic biota. For more information about impervious surfaces, water quantity, or pollutants, please see the *Impervious Surfaces*, *Water Quantity and Use*, and *Pollution* sections below.

To avoid or minimize negative environmental effects of impervious surfaces, developers and decision makers can implement actions to counter effects of impervious surfaces and stormwater runoff on natural resources. Narrower roads can be used in some cases to reduce the amount of impervious surface, and swales and rain gardens can be installed to reduce the amount of runoff. Land use planning, zoning, addition of parks, and natural area acquisitions are used in many communities to incorporate green infrastructure into developed landscapes that can help maintain functional floodplains, stream flows, water quality, fish and wildlife habitat, and other ecosystem functions and public benefits. Permeable pavement has been used to reduce stormwater runoff and pollution transport (Brattebo and Booth 2003, Drake, Bradford and Marsalek 2013), among other negative effects of impervious surfaces. Some states and localities have laws intended to control erosion and sedimentation (USEPA 2024, Fairfax 2024, Virginia.Gov 2024).

Mining and Mineral Extraction

The United States has a history of mining that dates to the early 17th and 19th centuries when iron, lead, silver, copper, and coal were discovered and mined by early settlers of New England, Missouri, and the Mid-Atlantic states. Today, all states and Puerto Rico produce mined materials or extract minerals from below the Earth's surface. Mined materials include fuels (e.g., coal, oil, and gas) and building materials (e.g., sand, gravel, and clay). Extracted minerals include rare Earth minerals, aluminum, and copper. There are no readily available summary data to illustrate the extent of the various forms of mining; however, a 1975 Corps of Engineers study on strip mining estimated 4.4 million acres and approximately 13,000 miles of rivers and tributaries were disturbed or adversely impacted by surface coal mining (USACE 1979).

Environmental effects from mining and mineral extraction including habitat loss, reduction in surface and ground water quality, reduction in air quality, and pollution from mining waste disposal. Mining activities can affect downstream water chemistry, which may in turn affect species, their habitat, and other resources on which they depend. Studies have shown that mining-impacted waterways often contain elevated levels of arsenic, selenium, iron, aluminum, manganese, and sulfate. These waters typically have lower alkalinity concentrations and lower pH, while specific conductivity and total suspended solids are typically higher compared to streams unimpacted by mining (Skogerboe, et al. 1979, Wangsness, et al. 1981, Zuehls, Fitzgerald and Peters 1984, Herlihy, et al. 1990, Bryant, McPhilliamy and Childers 2002, Petty, et al. 2010, USEPA 2011, Presser 2013). These environmental impacts have caused decreases in macroinvertebrate communities (Hartman, et al. 2005, Pond, et al. 2008) and fish (Hopkins and Roush 2013, Giam, Olden and Simberloff 2018, Sergeant, et al. 2022) downstream of mining activities. For some sites, even after years of reclamation and restoration efforts, the sites continue to show low levels of forest productivity compared to nearby native forests (Groninger, Fillmore and Rathfon 2006).

In 1977, the United States passed the Surface Mining Control and Reclamation Act (SMCRA), "the primary federal law that regulates the environmental effects of coal mining in the United States" (OSMRE and SMCRA Programs 2024). SMCRA required minimum standards for coal mining to be used nationwide with an aim to protect the environment. SMCRA also allowed states to enact stricter regulations. Mining activities that occurred after SMCRA were required to return the mined lands to pre-mining conditions as much as possible, including successful revegetation. Acid-producing pyritic (FeS_2) materials now need to be isolated below the final surface of the revegetated area. Post-SMCRA mine soils (i.e., 2002) had a higher pH than the finer-textured mine soils from mines sampled in 1980. In addition to the implementation of SMCRA, many technology improvements have occurred over the last several decades and more recent mining activities have bored deeper into unweathered rock as opposed to weathered rock closer to the surface (Daniels, Haering and Galbraith 2004).

Water Quantity and Use

Use of water is based on increasing demand, fueled by population and economic growth. Water availability varies based on annual weather patterns and may change in the future as climate change affects weather patterns and water supply. Year-round water withdrawals are no longer available from many lakes and streams to protect aquatic species and existing water rights in many western states.

Freshwater withdrawals increased from 1950 until the 1980s, after which surface water use appeared to decrease even with population increases. In 2015, water use across the United States was estimated to be 322 billion gallons per day, which is the lowest overall withdrawal since 1970 and was 9% less than the 2010 estimate. Freshwater withdrawals accounted for 87% of the total and saline-water withdrawals accounted for 13%. Between 2010-2015, fresh surface-water withdrawals decreased by 14%, fresh groundwater withdrawals increased by 8%, and saline surface-water withdrawals decreased by 14%. Overall, the largest water uses in 2015 were thermoelectric power (decreased by 18%) and irrigation of agricultural lands (increased by 2%). Other water uses decreased in by 2015: public supply (7%), self-supplied domestic (8%), Self-supplied industrial (9%), and aquaculture (16%). Mining reported a 1% increase in withdrawals and livestock withdrawals remained essentially the same (Dieter, et al. 2018).

Thermoelectric power plants use water to cool steam used to drive thermoelectric generators. Nearly all (100%) water used in thermoelectric power plants is surface water, and 72% was from freshwater sources. Thermoelectric power withdrawals were greatest in TX, and when combined with IL, MI, AL, and NC, these five states accounted for 40% of freshwater withdrawals for thermoelectric power. Saline surface withdrawals were primarily used in FL, NY, and MD (53% of total saline withdrawals for thermoelectric power) and 90% of saline groundwater withdrawals occurred among NV, CA, FL, and HI (Dieter, et al. 2018).

Irrigation is used to grow plants for agriculture and horticulture (i.e., forest nurseries, seed orchards, other crops), to maintain green spaces (i.e., golf courses, parks, turf farms, cemeteries, and other landscaping), and for other water-related processes (i.e., frost protection, chemical application, weed control, harvesting, dust suppression, and leaching salts from the root zone). In 2015, irrigation accounted for 42% of total freshwater withdrawals. Most irrigation withdrawals (81%) were occurred in the western United States (i.e., ND south to TX and west to the Pacific Ocean). Groundwater was the primary source of irrigation water in CA, NE, TX, KS, SD, and OK and surface water was the primary source elsewhere in the West (Dieter, et al. 2018).

Effects associated with water withdrawals include lower water volumes in rivers, streams, lakes, and aquifers; modification of natural flow regimes; water shortages downstream and during drought periods; reduced water quality; and degradation of wildlife habitat (Wissmar, et al. 1994, Saha and Quinn 2020). Irrigation also includes effects from water storage and drainage, increased water temperatures (which can become thermal barriers for salmonids and other aquatic species), introduction of pollutants (such as runoff containing pesticides and fertilizers), and increased sediment levels (Wissmar, et al. 1994, Krupka 2005).

There have been several attempts to reduce impacts from water withdrawal and water-diversion activities. Some efforts to minimize effects to anadromous fish were undertaken relatively early

(Palmisano, Ellis and Kaczynski 2003), such as screening of irrigation diversions in the 1930s, although the screens did not protect all life stages, nor were they adequately maintained. More recently, the EPA published a handbook for developing watershed plans to restore and protect United States waters (USEPA 2008), in which they outline information needed for a watershed plan to meet water quality standards and protect water resources; many states have similar guides. Some projects were proposed specifically to address flow issues. For example, between 2000 and 2004, the Salmon Recovery Funding Board (SRFB 2005) funded projects to alter river flows over 85 acres, slowing the stream flows to enhance salmon spawning and rearing habitats. Many similar projects exist across the country (NOAA 2023, WDOE 2023, YWA 2023) (WDOE 2023) (YWA 2023).

Pollution, Contaminants, and Pesticides

Pollution is the introduction of harmful materials into the environment. Pollutants can include a wide variety of chemicals such as excess nutrients, heavy metals (e.g., mercury, lead), persistent organic pollutants like polycyclic aromatic hydrocarbons (PAHs), poly-bromated diphenyl ethers (PBDEs), hazardous waste, microplastics, and others. The types and concentrations of pollutants in the environment vary depending on the pollutant's chemical characteristics and sources and can be influenced by environmental factors, habitat type, and region. Altogether, pollutants represent a complex network of environmental stressors that contribute to habitat degradation, cause toxic effects in listed species, and impair ecosystems around the world. Given the wide diversity of pollutants that currently contaminate the habitat of listed species, we are not able to fully address the breadth of impacts that pollutants have on the environmental baseline of listed species. Here, we provide a general survey of different types of pollutants, a summary of their impacts on the environment, and description of how they contribute to the environmental baseline of listed species.

Chemicals associated with land use practices, like pesticides and fertilizers, are used on agricultural and developed lands and can enter the environment through stormwater runoff and spray drift (see *Use of Pesticides* section below for further discussion of the impact of pesticides on the environmental baseline). The EPA estimated that 50% of the nation's streams (approximately 300,000 miles) and 45% of the nation's lakes (approximately seven million acres) were in fair to poor condition because of nutrients commonly found in fertilizers, like nitrogen or phosphorus, relative to reference condition waters (USEPA 2013). Pesticides and excess nutrients can impair water quality, adversely affecting aquatic species inhabiting polluted streams and terrestrial species that rely on contaminated water sources. Additionally, excess nutrients can trigger harmful algal blooms, which result in broad ecosystem effects like depleted dissolved oxygen resources for aquatic species, altered pH, reduced light availability, and increased turbidity (USEPA 2024). Some harmful algal blooms produce potent toxins and cause a number of illnesses in wildlife and humans, such as paralytic shellfish poisoning. Harmful algal blooms commonly result in major environmental impacts, such as large-scale fish kills and hypoxic dead zones (Hallegraeff, Anderson and Cembella 1995).

Inorganic pollutants, including heavy metals like lead, mercury, and arsenic, occur naturally in the environment, but can accumulate as pollutants because of human activities. Heavy metals are widely used in industrial, domestic, agricultural, medical, and technological applications. These pollutants can enter the environment through hazardous material spills, industrial emissions, vehicle emissions, stormwater runoff, and through common products like discarded batteries, paints, and dyes. Given their wide use, heavy metal contamination is a world-wide phenomenon. Heavy metals can be highly toxic, causing a wide range of effects like disruption of organ systems and metabolic function, developmental effects, neurological disorders, or other illnesses in wildlife and humans (Timothy and Williams 2019). Heavy metals do not degrade and thus can persist in the environment indefinitely without any remediation efforts.

Similarly, organic pollutants cover an incredibly wide array of chemical types. Many organic pollutants, such as PBDEs, polychlorinated biphenyls (PCBs), and chlorinated compounds (including dioxins), are (or previously were) components of manufactured goods and their widespread use facilitates environmental contamination on a global scale. Some organic pollutants, such as PAHs, dioxins, and microplastics, are byproducts of industrial processes like combustion or leaching, or form during waste disposal and are unintentionally released into the environment. Regardless of their origin, organic pollutants are widespread and persistent in the environment. Their chemical characteristics (e.g., low water solubility, high volatility, slow degradation) make them long-lasting environmental contaminants as they permeate soils, are transported long distances by air, and accumulate in animal tissues, even long after removal of original sources.

Organic pollutants can have a variety of toxic effects, ranging from acute toxicity of various organ systems to long-term chronic effects like altered reproduction, endocrine disruption, and carcinogenesis. In the 2007 National Lakes Assessment, EPA found that only 56% of the nation's lakes were in good biological condition and several contaminants, including mercury, PCBs, dioxins, furans, and DDT (an insecticide), were widely distributed across surveyed lakes. Of particular concern is that some of these harmful pollutants (e.g., PCBs and DDT) remained detectable 30+ years after they were banned for use in the United States because of their human and environmental effects (USEPA 2007). As suggested by the EPA results, some chemicals and their breakdown products persisted in the environment because bacteria and chemical reactions break them down slowly (PSWQAT 2000). Although the effects from many of these chemicals have been at least partially analyzed, multiple substances are present in the habitat and/or biota and little is known about their synergistic effects.

Other sources of toxic contaminants (including inorganic and organic pollutants mentioned previously) include solid waste and leaching from landfills, discharges of municipal and industrial wastewater, improper disposal of hazardous waste (e.g., printing, dry cleaning, auto repair shops), and channel dredging, which can result in resuspension of contaminated sediments. Discharges from wastewater treatment plants may be treated prior to discharge into receiving waters, but some persistent, bio-accumulative, endocrine-disrupting, or toxic compounds often remain in the water (Bennie 1999, CSTEE 1999, Daughton and Ternes 1999, Servos 1999). Stormwater runoff is another significant contributor of non-point source water pollution and can contain complex mixtures of multiple chemical and biological contaminants, which can have devastating effects on fish, like salmonids (KCDNR and WSCC 2000, Chow, et al. 2019), reefs, seagrass beds, and other aquatic life. The presence of roads and other impervious surfaces increase the distance pollutants can travel throughout runoff because they prevent water absorption into the ground, greatly exacerbating the environmental impact of many types of pollutants.

Even if contaminated areas are relatively small, their effects can be far-reaching and long lasting. Many pollutants, particularly those that have low solubility like organic pollutants, are taken up by living organisms through a variety of routes of exposures, such as inhalation, dermal contact, or ingestion. Many pollutants can biomagnify within an ecosystem, where body burdens disproportionately increase with increasing trophic levels. Consequently, predators can have very high contaminant levels, even if they have spent little or no time in contaminated areas.

Due primarily to risks to human health, much attention was given to hazardous dump sites and other areas of high pollution in the 1970s. In 1980, Congress established the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), which allows the EPA to clean up contaminated sites, or "Superfund" sites. CERCLA also forces responsible parties to either clean up their pollutants or reimburse the EPA for their efforts. CERCLA authorizes short-term removals and long-term remedial responses, depending on the nature of the contaminated site and the urgency of human and environmental health risks (USEPA 2024b). Many Superfund sites exist across the country and success stories include Otis Air National Guard Base/Joint Base Cape Cod in MA, Brick Township landfill in NJ, Tobyhanna Army Dept in PA, Kerr-McGee Chemical Corp in MS, Celotex Corporation in IL, the USDOE Pantex Plant in TX, Kansas City Structural Steel, Libby Asbestos in MT, and Black Butte Mine in OR (USEPA 2024c).

Use of Pesticides

Pesticide use is a common practice to kill or manage unwanted plants, animals, and other pests (e.g., fungi, microbes). Many classes of pesticides are used for targeted pests: herbicides (i.e., plants), insecticides, rodenticides, fungicides, among others. In general, pesticides are beneficial to foresters and residential developers through control of unwanted or invasive non-native plants and aid in restoration of native habitat. They are beneficial to agriculture through control of pests that destroy crops, outcompete crops, degrade soils or water, and affect livestock. Pesticides can increase food production, increase profits for farmers, and prevent spread of diseases. Pesticides also benefit human health by killing pests such as mosquitos that that carry and transmit diseases (e.g., malaria, West Nile virus, and Zika).

When pesticides are applied to land, plants, or animals, they can enter air, water, and soil across the environment. How long pesticides remain in the environment varies with the chemical itself (i.e., how easily it degrades) and environmental conditions (i.e., soil water content) when its applied and after application (Arias-Estévez, et al. 2008). During a 10-year study by the U.S. Geological Survey (1992-2001), they detected pesticides in more than 90% of stream water samples, 80% of fish samples, and 50% of bed-sediment samples collected across the country (n=186). Pesticides were detected at concentrations above benchmarks for the protection of aquatic life in 50% of streams tested nationwide, 83% of streams in urbanized areas, and 94% of streambed sediments (Gilliom, et al. 2006). They were common throughout the year in streams of developed watersheds dominated by agriculture, urban, and mixed land uses. Fish and sediment in streams were contaminated with organochlorines like DDT, many of which have not been in use for years due to known environmental impacts. Other similar studies showed that pesticides were frequently detected in groundwater samples and concentrations were often below human-health benchmarks, but they did not assess wildlife or other environmental benchmarks (Toccalino, Lindsey and Rupert 2014, Bexfield, et al. 2021).

Pesticide use as part of past federal and non-federal actions has resulted in impacts to listed species, their habitats, and other species on which listed species depend. Pesticides affect taxa groups differently. For example, insecticides are targeted for insect pests, so they typically have greater effects on listed insects and potentially predators of insects than on other taxa groups. In general, pesticides have been documented to affect bird eggshell thickness, fish behavior and reproduction, insect behavior and survival, and many unintended indirect effects (D. Pimentel 1971) (Köhler and Triebskorn 2013).

Some federal actions have undergone section 7 consultations related to pesticide use. For example, the USDA Animal and Plant Health Inspection Service (APHIS) Pest Program uses pesticides to achieve its mission and has consulted with the Service on multiple occasions. APHIS's implementation of these activities is supported by a well-established program infrastructure that includes environmental compliance, training, monitoring, and reporting. Most APHIS activities have occurred on non-federal lands.

Aquatic Habitats

Wetlands

Wetlands perform functions that contribute to the health of ecosystems used by many species. There are many kinds of wetlands including tidal salt marshes, mangroves, freshwater marshes, swamps, riparian forests, and peatlands (W. J. Mitsch, et al. 2009). Wetlands store atmospheric carbon, protect clean water, maintain cool water temperatures, retain sediments, store and desynchronize flood flows, maintain base water flows, mitigate storm damage to coastal areas, and provide food and cover for many species of fish, birds, aquatic organisms, and other wildlife (Mitsch and Gosselink 1993, Beechie, Beamer and Wasserman 1994, W. J. Mitsch, et al. 2009). Wetlands also improve water quality through nutrient and toxic-chemical removal and/or transformation (Hammer 1989, Mitsch and Gosselink 1993).

The United States originally contained almost 392 million acres of wetlands. Between the 1780s and the 1980s, 118 million acres of wetlands were lost because of human activities. Wetlands were often excavated or filled to create upland for real estate development or converted to agriculture (Duke and Krucynski 1992). Arkansas, California, Connecticut, Illinois, Indiana, Iowa, Kentucky, Maryland, Missouri, and Ohio lost 70% or more of their original wetland acreage. California lost an estimated 91% and Florida lost 46% of its 1780s total (Dahl 1990). Between 2006 and 2009, approximately 13,800 acres of wetlands were lost per year (Dahl 2011). In 2019, wetlands occurred on approximately 116.4 million acres of the conterminous United States and most of them (95%) are freshwater (Lang, Ingebritsen and Griffin 2024). Most wetlands were vegetated (i.e., 92% freshwater and 80% saltwater), primarily freshwater emergent or scrub-shrub wetlands and salt marsh. Net wetland loss between 2009-2019 increased by over 50% compared to 2004-2009, most of which was loss of vegetated wetlands (Figure 5, Figure 6). They believe some loss of saltwater wetland vegetated indicates a future loss of wetland to sea level rise and coastal storm impacts. Many remaining wetlands have been degraded and have reduced functionality now compared to the 1780s. (Lang, Ingebritsen and Griffin 2024) also documented an increase in non-vegetated wetlands, a shift which reduces the prosperity, health, and safety of wetland and nearby communities compared to vegetated wetlands.

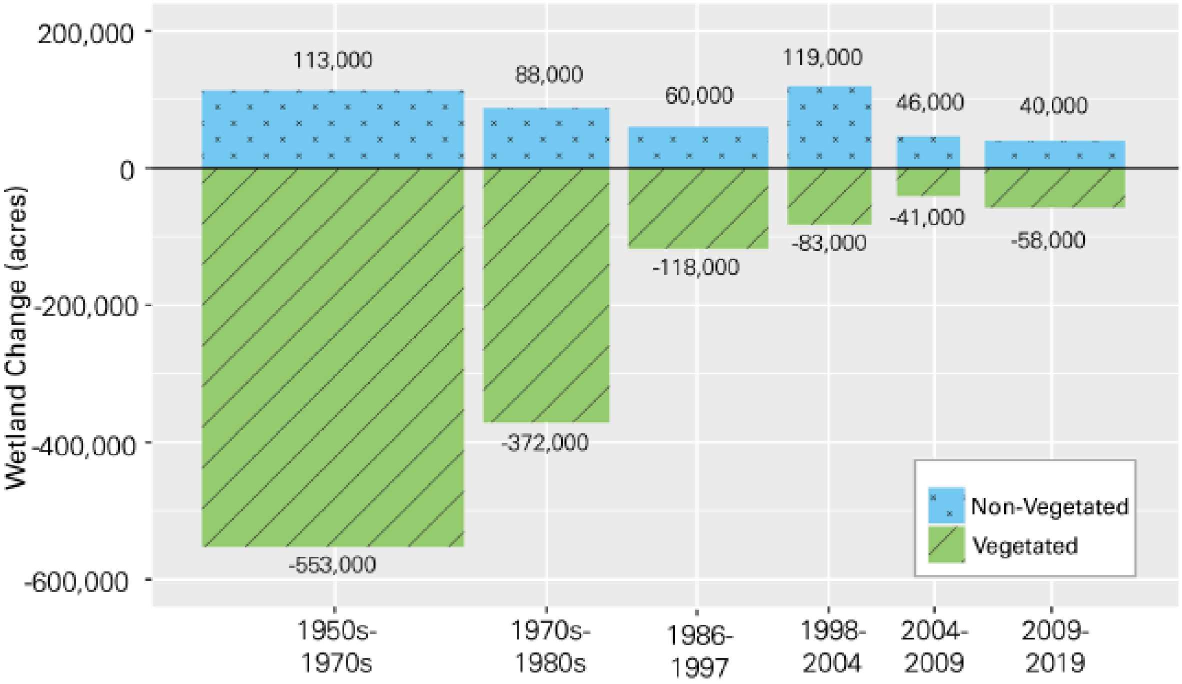

Figure 5. Average net annual non-vegetated and vegetated freshwater wetland acreage change estimates for the conterminous United States from the 1950s-2019. Figure on page 21 of (Lang, Ingebritsen and Griffin 2024).

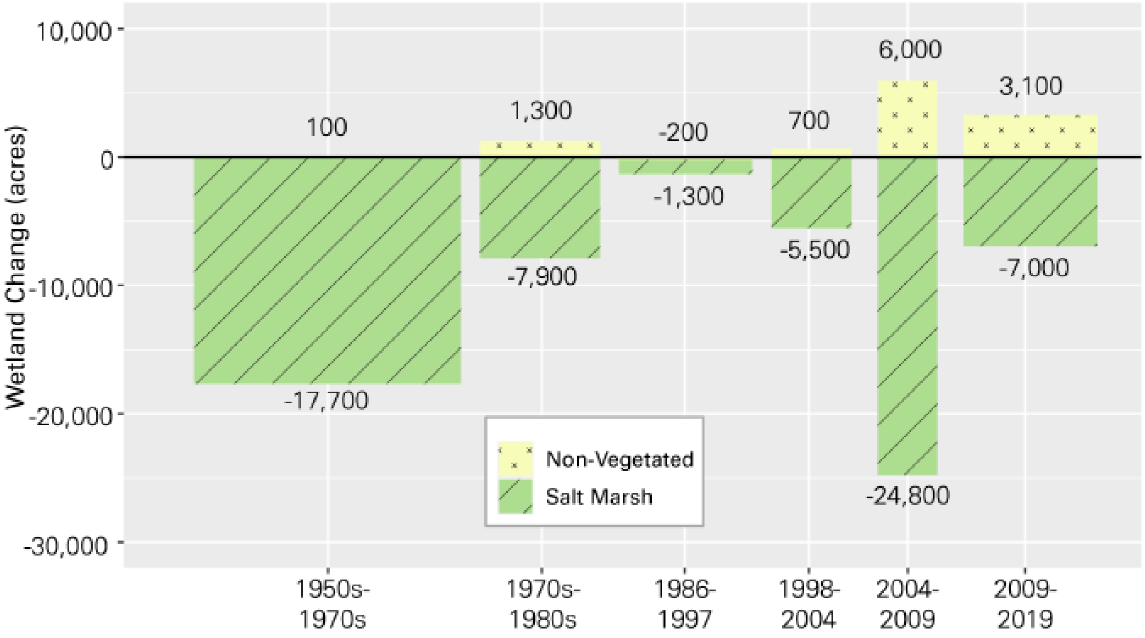

Figure 6. Average net annual salt marsh and non-vegetated saltwater wetland acreage change estimates for the conterminous United States from the 1950s-2019. Figure on page 21 of (Lang, Ingebritsen and Griffin 2024).

Various factors have contributed to wetland loss and degradation including agricultural development, urbanization, timber harvest, road construction, and other land-management activities. These activities affect wetlands and are responsible for much of the loss of riparian buffers (70% of the original area of riparian ecosystems) that we have seen in the United States (Swift 1984). Riparian areas, the transitional zone between streams and uplands, protect the stream from excess sediments, sequester pollutants, attenuate peak stream flows during floods, and act as holding areas for water that is released back into the stream during times of low flow. They create habitat features essential for wildlife, like pools, riffles, slack areas, and off-channel habitats. Riparian areas are affected by development, logging, recreation, grazing, mining, and water diversions. Though efforts to create and restore wetlands and riparian buffers have dramatically reduced the rate of destruction or degradation, many wetland habitats continue to be lost. Different riparian widths are required depending on the characteristics of a particular riparian zone. For many small stream systems, riparian areas are highly degraded or no longer exist, and their restoration is precluded by existing development. Although functional riparian areas have the capacity to mitigate for some of the adverse impacts of development (Morley and Karr 2002), they cannot effectively address significant impacts from changes to stream hydrology resulting from significant losses of forest cover (May, et al. 1997, Booth, Hartley and Jackson 2002).

All waterbodies in the United States have been affected by anthropogenic stressors, which often lead to long-term environmental degradation, lower biodiversity, reduced primary and secondary production, and a lower capacity or resiliency of the ecosystem to recover to its original state in response to natural perturbations (Rapport and Whitford 1999). Freshwater habitats are among the most threatened ecosystems in the world (Leidy and Moyle 1998). Reviews of aquatic species' conservation statuses for the past three decades have documented the cumulative effect of anthropogenic and natural stressors on freshwater aquatic ecosystems, resulting in a significant decline in the biodiversity and condition of indigenous fish, mussel, and crayfish communities (Taylor, et al. 2007, Jelks, et al. 2008).

Rivers and Streams

Free-flowing rivers regularly flood and recede, collecting and depositing sediment materials both laterally and downstream. Rivers carry sediment and nutrients down river, eventually depositing it in the deltas and estuaries where freshwater enters saltwater. Natural rivers typically are narrower, have more riparian and bank cover, more habitat diversity, and higher pool volume than rivers that have been managed for transportation or other purposes. Past land use can leave legacy effects on streams and rivers and restored riparian zones may not serve the same ecosystem function as the original habitat (Wohl and Merritts 2007).

Many streams have been channelized, diverted, and confined through the construction of dikes, levees, berms, revetments, embankments, and other structures. Channelization (and often its associated bank armoring) is used to reduce flood damage to property, exclude water, or store water for future use. While these changes may be favorable to property owners or project proponents, such actions often result in substantial changes to aquatic and terrestrial habitats and their use by wildlife. Channelization results in simplification of the stream and has resulted in changes in flow, velocity, temperature, and movement of water (Tarplee, Louder and Weber 1971, Bolton and Shellberg 2001). Channelization also degrades and fragments migratory corridors, eliminates historical foraging, migration, and overwintering habitats (Bolton and Shellberg 2001), and changes songbird and small mammal communities (Possardt and Dodge 1978).

Barriers to Fish Movement

Water management structures (i.e., dams, dikes, levees) used for flood control, conversion of wetlands to agriculture, bank protection, water supply needs, power generation, recreation, or other/urban development can reduce connectivity among and within watersheds. By 2024, 600,000 miles of river in the United States (conservatively, 17%) have been modified by over 75,000 large dams (IWSRCC 2024). Dams serve as barriers to fish passage (Limburg and Waldman 2009) and delay or block passage of anadromous fish to upstream reaches. The ability of anadromous fish to access areas above man-made barriers is important for the survival of individuals and populations of the species and for the integrity of the ecosystems they support (Cederholm, et al. 2000). Fish movement is also extremely important to the survival of many freshwater mussel species who rely on fish hosts for their reproductive strategy (Haag 2012). Barriers to fish passage contribute to fragmented mussel populations. Staging and spawning adults are prey for upstream aquatic and terrestrial predators. Rich marine-derived nutrients from anadromous fish are transported to the reach of stream in which they die, into the lower reaches of the stream and estuary through downstream drift, and across habitat or ecosystem boundaries by mobile mammals, birds, and fish (Doughty, et al. 2015, Mattocks, Hall and and Jordaan 2017).

Controlled flow from a dam often slows river movement and changes the natural cycle of river flows, resulting in areas that are either drier than normal (because the water is being held behind the reservoir) or flooded by much higher levels of water. Changing the depth and flow of rivers affects water quality, temperature, and material transport (e.g., sediments, nutrients, and large woody debris). Reservoirs fill with sediment and less sediment reaches downstream deltas and estuaries. For example, in a press release about the Iron Gate Dam drawdown, the Klamath River Renewal Corporation mentioned that 17-20 million cubic yards of sediment has been trapped behind three dams slated for removal (Brownell 2024).

Many projects aimed to mitigate or minimize effects of past or present dams or reservoirs on downstream habitats exist across the country (USFWS 2022, NRCS 2023, NOAA 2023). Fish ladders were added to some waterways to aid in fish passage, but some life stages of fish still cannot get through. Over 1,200 dams were removed across the United States by 2017, according to Bellmore, et al. (2017). Few studies have assessed changes to habitat or ecosystem biodiversity after dam removal (Bellmore, et al. 2017), but some non-native, invasive species (i.e., Asian carp (Cyprinidae) and lampreys (Petromyzontidae)) benefit from dam removal and use of fish ladders. Fish ladders also encourage fish congregations, which facilitates disease spread and resource competition. In some locations, dams are being used intentionally to limit movement of an unwanted or invasive fish species from affecting target species, like trout, chubs, and salmon (McLaughlin, et al. 2013). In addition, when dams are removed, trapped sediment (often millions of cubic yards of sediment) runs downstream (Brownell 2024) and can change waterflow and cause turbidity.

Improperly installed, sized, or failed culverts have been identified as barriers for fish movement and migration. Although historically placed, culverts that serve as fish-passage barriers continue to impede fish in many streams. Several groups have made efforts to inventory and remove fish barriers under their jurisdictions, often either removing barrier culverts or replacing them with a more-suitable structure. Removal of a barrier culvert is often undertaken when a crossing is no longer needed (Peck 2005). If a crossing is necessary, other options include bridges or other specific methodologies: stream simulation, roughened-channel design, no-slope methodology, or hydraulic design.

Estuaries

Estuaries are some of the most productive ecosystems in the world (Correll 1978) and they include salt marshes, mangrove forests, mud flats, tidal streams, rocky intertidal shores, reefs, and barrier beaches. Estuaries are home to thousands of species of birds, mammals, fish, and other wildlife in the United States. Salt marshes filter pollutants that flow through it and trap nutrients, which explains why salt marshes serve as nursery and breeding grounds for many wildlife species. Estuaries and associated wetlands also stabilize shorelines and protect nearby coastal and inland areas from flooding and other storm damage (NOAA 2024). Many animals, including most commercially important fish (e.g., salmon, sturgeon), sea turtles, and waterbirds, depend on estuaries for nursery, rearing, foraging, or migration habitat.

In estuaries that support salmon, changes in habitat and food-web dynamics have altered their capacity to support juvenile salmon (Bottom, et al. 2005, Fresh, et al. 2005, Allen, Pondella and Horn 2006, LCFRB 2010). Diking and filling reduced the tidal prism, reduced freshwater inflows, change sediment flows, and eliminated emergent and forested wetlands and floodplain habitats. Dikes may have marked effects on tidal channel biota, specifically on the seaward side of the structure, and their construction may result in decreased sinuosity and complexity, preventing energy dissipation during flood events in some places (Hood 2004). Similarly, dredging activities in shallow coastal estuaries can increase the tidal prism, increase salinities, increase turbidity, release contaminants, lower dissolved oxygen, and reduce nutrient outflow from marshes, resulting in a host of negative consequences to these ecosystems. Diking, filling, and dredging has: reduced fishery productivity; contributed to land losses (e.g., Louisiana, Florida); contributed to fish kills; reduced avian habitats and use; and reduced the resiliency of estuarine areas to stochastic events (e.g., hurricanes) (Johnston 1981, Nightingale and Simenstad 2001).

The Estuary Restoration Act of 2000 was developed to address wetland loss and damage from human activities, and the U.S. Army Corps of Engineers (USACE) received funding for project implementation across the country. For example, Florida has had two large restoration projects underway to address environmental problems caused by dikes. The first is the Kissimmee River Restoration Program authorized by Congress and initiated in 1992. In July 2021, the South Florida Water Management District and USACE Jacksonville District completed the project's construction. Overall, they restored >40 mi^2 of the river floodplain, 20,000 ac of wetlands, and 44 mi of historic river channels (SFWMD 2021). The second is the Comprehensive Everglades Restoration Plan, which was authorized by Congress in 2000 to "restore, preserve, and protect the south Florida ecosystem while providing for other water –related needs of the region, including water supply and flood protection" (SFNRC 2016). The greater Everglades ecosystem historically encompassed 18,000 sq. miles from central Florida to the Florida Keys. Water flowed south into Lake Okeechobee and then spilled over its banks into the sawgrass plains, open water sloughs, rocky glades, and marl prairies and finally into the Gulf of Mexico and Florida and Biscayne Bays. The USACE installed a massive network of canals, levees, and water conservation areas that blocked sheet flow to urban areas and provided water for dry season use. The Comprehensive Everglades Restoration Plan is ongoing (NPS 2022). Mitigation of losses of estuarine marsh in the mid-Atlantic and Gulf of Mexico may roughly keep pace with the losses of the last two decades, but they have not reversed the large losses of the mid-twentieth century (Dahl 2011).

In Washington, restoration efforts focused on the benefits of restoring ecosystem functions affected by diversion structures. In 2002, the Nisqually Tribe removed a portion of a dike in Red Salmon Slough, reconnecting 31 acres of former pastureland to the Nisqually River Estuary (SPSSEG 2002, Carlson 2005). This action was undertaken to benefit juvenile salmonids, other fish species, and migratory birds. At Spencer Island in Snohomish County, two 250-foot-long breaches were made in an estuary dike to reconnect approximately 250 acres of estuarine marsh (Carlson 2005). Other similar restoration work has occurred across the country (USACE 2013).

Shorelines

Significant shoreline development and urbanization has occurred throughout the action area. Habitats at risk from shoreline alteration include riparian buffers, freshwater habitats (e.g., streams, lakes), and shallow subtidal, intertidal, and shoreline habitats known collectively as the "marine nearshore." Submerged aquatic vegetation (i.e., seagrass beds) on the Pacific and Atlantic coasts grow in the intertidal zone and in mud and sand in the shallow sub-tidal zone. Turtle grass, shoal grass, manatee grass, and wigeon grass occupy similar ecological niches in the estuaries of the northern Gulf of Mexico. Many of these areas house migratory shorebirds and waterbirds, spawning and rearing salmonids, shellfish reefs, and other sensitive wildlife (Duke and Krucynski 1992).

Portions of nearshore and shoreline habitats have been altered with vertical or steeply sloping bulkheads and revetments to protect various developments and structures (e.g., railroads, piers) from wave-induced erosion, stabilize banks and bluffs, retain fill, and create moorage (i.e., docks, harbors) for vessels (BMSL et al. 2001, Prosser, et al. 2017). Depending on placement and other shoreline characteristics, shoreline armoring can interrupt the natural inputs of sand from landward bluffs and result in sediment deficits within the landscape (Prosser, et al. 2017). Docks, bulkheads, and other shoreline developments likely contribute to the reduction in submerged aquatic vegetation and other spawning and rearing areas for forage fish. For example, losses of sensitive and highly productive submerged aquatic vegetation habitats were estimated between 20-100% in northern Gulf of Mexico estuaries (Handley, Altsman and Demay 2007). In many cases, submerged aquatic vegetation serves as an indicator of lake or shoreline health and die offs result from decreases in water quality or contamination (Moorman, et al. 2017) from development on or near the shoreline.

Invasive Species

Invasive species are non-native species capable of causing great economic or ecological impacts in areas where they become established. Ecological impacts from biological invasion include predation, disease transmission, competition (for food, light, space), and hybridization. The rate of species invasion increased over the past several decades due to human population growth, alterations of the environment, and technological advances that allow for the rapid movement of people and products (Pimentel, Zuniga and Morrison 2005). Invasive species are considered a contributing factor in the decline of half of the imperiled species in the United States (Wilcove, et al. 1998). Based on factors affecting species associated with island ecology (e.g., small populations, small ranges, high rates of endemism), the impact of invasive species is even greater.

An estimated 50,000 or more non-native terrestrial and aquatic species are believed to have been introduced into the United States across its history. Non-native mammals include dogs, cats, horses, sheep, pigs, goats, deer, and rodents. About half of these invasive species are plants, 5,000 of which were introduced to the United States as food or ornamental plants and have since escaped and established on their own. In some cases, non-native plants are capable of completely dominating new habitats, forming dense monocultures, and completely excluding other native plants (Pimentel, Zuniga and Morrison 2005). In addition, invasive plants can accelerate carbon cycling, alter hydrologic cycles, reduce sunlight penetration in aquatic habitats, and change nutrient cycles (Poland, et al. 2021). Approximately 97 non-native bird species exist in the United States with self-sustaining populations, 56% of which are considered pest species. Many non-native birds compete with or displace native birds, and they are vectors for avian diseases. Some invasive birds were released intentionally as biocontrol agents (e.g., common myna [*Acridotheres tristis*] to control cutworms and armyworms in sugarcane in HI and house sparrows [*Passer domesticus*] to control canker worms). About half (35/69) of the non-native birds introduced to HI between 1850-1984 remain on the islands. As of 2005, 138 non-native fish were introduced into the United States and at least 44 native fish species are threatened or endangered because of invasive fish. Approximately 53 species of reptiles and amphibians have been introduced to the United States and they often prey upon native species. More than 4,600 non-native invertebrate species are found in the United States, some of which are well known for vast ecological impacts (e.g., balsam woolly adelgid [*Adelges piceae*], red imported fire ant [*Solenopsis invicta*], and European green crab [*Carcinus maenas*]), including the decline or extirpation of native species (Pimentel, Zuniga and Morrison 2005).

Once an invasive species is established, management strategies available include prevention of further spread, early detection, eradication, control, and adaptation. Prevention includes actions like ship inspections and eradication at entry ports before it is brought into the location. If a species is missed during prevention efforts, it can be detected early and potentially eradicated, particularly if there are only a few individuals or a small population. Control includes efforts to limit the growth and spread of an established species or population (e.g., physical barriers). Adaptation can include use of pesticides on the invasive species or harvest of the species. The optimal choice for managing invasive species varies with the species of concern, environment affected, and policy and fiscal considerations (Marbuah, Gren and McKie 2014, Espanchin-Niell 2017). The Lacey Act of 1900 is a tool used to limit transportation of “injurious” wildlife. In 1996, the United States amended the Nonindigenous Aquatic Nuisance Prevention and Control

Act of 1990 to include the National Invasive Species Act of 1996, which aims to prevent introductions and spread of invasive aquatic species in the Great Lakes through ballast water.

Collection and Harvesting

Some ESA-listed species, such as salmonids and freshwater mussels, are economically important species that are harvested as food. Harvesting and exploitation, often associated with the pearl industry, is identified as a contributing factor to 18% of the imperiled freshwater mussels of the United States (Strayer, et al. 2004). After species are listed as threatened or endangered under the ESA, they receive protection from overharvesting because harvest requires a permit issued by the Service, and permits are generally limited to certain categories of activities that would benefit the conservation and recovery of the species. Although harvest is a historical threat to many ESA-listed species and illegal harvest is still likely to occur to some degree, it rarely affects species substantially now, and it is not expected to greatly affect currently listed species in the action area in the future.

Climate Change

All species discussed in this Opinion are or may be threatened by the effects of global climatic change. The Intergovernmental Panel on Climate Change (IPCC) estimated that the last 30 years were likely the warmest 30-year period of the last 1,400 years, and that global mean surface temperature change will likely increase between 0.3-0.7 degrees Celsius during the next 20 years. The IPCC observed global mean surface temperature for the decade 2006-2015 was 0.87 °C higher (likely between 0.75°C and 0.99°C) than the average between 1850-1900 (IPCC 2018). This temperature increase is greater than what would be expected by natural climatic variability alone, considering recorded temperatures over the past 1,000 years (Crowley and Berner 2001). Increasing atmospheric temperatures have contributed to changes in the quality of freshwater, coastal, and marine ecosystems and the decline of populations of endangered and threatened species (Mantua, et al. 1997, Karl, Melillo and Peterson 2009, Littell, et al. 2009).

Climate change is also anticipated to impact the timing and intensity of seasonal stream flows (Staudinger, et al. 2012). Warmer atmospheric temperatures are expected to reduce snow accumulation, increase winter stream flows, cause spring snowmelt to occur earlier in the year, and reduce summer stream flows in rivers that depend on snow melt. As a result, seasonal stream flow timing will likely shift significantly in sensitive watersheds (Littell, et al. 2009). Changes in stream flow due to use changes in seasonal run-off patterns may alter predator-prey interactions and change species assemblages in aquatic habitats. For example, a study conducted in an Arizona stream documented the complete loss of some macroinvertebrate species as the duration of low stream flows increased (Sponseller, et al. 2010). As it is likely that intensity and frequency of droughts will increase across the southwest (Karl, Melillo and Peterson 2009), similar changes in aquatic species composition in the region are likely to occur. Warmer temperatures may also increase water use for agriculture, both for existing fields and the establishment of new ones in once unprofitable areas (ISAB 2007). If agriculture requires more water, streams, rivers, and lakes will experience additional water withdrawals and potentially higher contaminant loads from returning effluent.

Warmer global air temperatures are causing rapid melting of sea ice and global sea level rise. Between 1880 and the 2010s, global mean sea level increased between 21-24 cm, the fastest rate of sea level rise over the last 2,800 years. Higher sea levels worsen effects of coastal storms, storm surge, tidal flooding, and waves. Climate change is also anticipated to increase storm frequency and intensity, which would exacerbate these concerns. Wave action, beach inundation, marsh flooding, and general sea level rise affect coastal habitats and wildlife, including geomorphology and sediment cycling, and modify the future flood risk profile of communities and ecosystems (Sweet, et al. 2017).

Warming water temperatures attributed to climate change can have significant effects on survival, reproduction, and growth rates of aquatic organisms (Staudinger, et al. 2012). For example, warmer water temperatures have been identified as a factor in the decline and disappearance of mussel and barnacle beds in the Northwest United States (Harley 2011) and shifts in migration timing of pink salmon (*Oncorhynchus gorbuscha*), which may lead to high pre-spawning mortality (J. A. Taylor 2008). In Yellowstone National Park, climate warming resulted in wetland desiccation and declines in four amphibian species (McMenamin, Hadly and Wright 2008). Warmer water also stimulates biological processes that can lead to environmental hypoxia. Oxygen depletion in aquatic ecosystems can result in anaerobic metabolism increasing, thus leading to an increase in metals and other pollutants being released into the water column (Staudinger, et al. 2012). Effects of aquatic nuisance species invasions are also likely to increase as ecosystems become less resilient to disturbances (USEPA 2008). Invasive species that are better adapted to warmer water temperatures could outcompete native species that are physiologically adapted to lower water temperatures; such a situation already occurs along central and northern California (Lockwood and Somero 2011).

Other effects of climate change include decreases in sea ice, changes in sea surface temperatures, alterations in precipitation patterns, rises in sea level, and increased success of non-native, invasive, and pathogenic species. Biota may be forced to respond to climate-induced changes in their environment like altered reproductive seasons/locations, shifts in migration patterns, reduced distribution and abundance of prey, and changes in the abundance of competitors and/or predators. Climate change is most likely to have its most pronounced effects on species whose populations are already in tenuous positions (Isaac 2009, McElwee, et al. 2023).

The EPA has several programs and standards in place to help combat greenhouse gas emissions, and thereby combat climate change. In 2005, EPA created the Renewable Fuel Standard, which requires all fuels sold in the United States to contain a certain amount of renewable fuels to offset petroleum-based fossil fuels and reduce greenhouse gas emissions (USEPA 2023). EPA implements a carbon dioxide emission standard for commercial and large business aviation and a greenhouse gas emissions standard for passenger cars and light trucks for model years 2023-2026. The passenger standards are estimated to save over 3 billion tons of greenhouse gases up to 2050 (USEPA 2024).

Change of Ecosystem Function and Biodiversity Loss

The environmental and habitat changes discussed in the previous sections affect ecosystem function and biodiversity. Biodiversity, the variety of life in a community often measured in number of species and equity of those species (i.e., richness and evenness, respectively), has been declining globally and in the United States for decades. Many aspects of biodiversity and its effects on ecosystem function are unknown, but evidence supports that communities with higher biodiversity in terrestrial, aquatic, and marine ecosystems are more productive than monocultures in the same environments. Productivity comes from optimal use of limited resources, lower incidence of disease and herbivory, and higher nutrient stores and more nutrient-cycling feedbacks. Communities with higher biodiversity are more resistant to non-native species invasions because few resources are unconsumed and available for invaders. Highly diverse communities have a greater bacteria diversity, which makes them more resistant to some pathogens (Tilman, Isbell and Cowles 2014). Climate change and drivers of climate change exacerbate biodiversity loss across taxa and regions (McElwee, et al. 2023).

Insect Pollinator Decline

Of particular concern to national pesticide consultations is the documented insect pollinator decline that has occurred over the last several decades. Insects have been experiencing a worldwide decline in biomass, abundance, and diversity with potentially negative implications for plant pollination. Long term surveys in North America and Europe show terrestrial insects declined in abundance by an average of 9% per decade, whereas freshwater insects increased by 11%. The decline of terrestrial insects was estimated to be 0.92% per year while the increase of freshwater insects was estimated at 1.08% per year. The most compelling evidence for declines in terrestrial insect assemblages was found in North America. Strong evidence exists for both directional trends in temperate, Mediterranean, and desert climates. The declines appear to be associated with changes in land use. Moderate evidence exists for a negative relationship between terrestrial insect abundance trends and landscape urbanization and may be explained by habitat loss and light and/or chemical pollution (Van Klink 2020). Consequences of insect declines could impact ecosystems by reducing services like pollination and seed dispersal (Dornelas and Daskalova 2020). By 2010, there were already 54 studies covering 89 plant species that showed the most frequent proximate cause of reproductive impairment of wild plant populations in fragmented habitats was pollination limitation (Potts, et al. 2010). The scope of global and national pollinator decline has been evaluated in numerous studies and we summarized a few here. Over the last 10-30 years, many pollinators are at risk of extinction, and they have shifted or contracted their ranges due to several factors, including habitat loss, environmental changes, competition with invasive or non-native species, and potentially other reasons (McElwee, et al. 2023).

In Illinois, Burkle (2013) used historic data sets to determine the degree of change over 120 years in a temperate forest understory community. Results showed that 50% of bee species in the study area were extirpated and 46% of the original forb-bee interactions were lost (246 of 532), even though all 26 forbs remained present. More specialist pollinators were lost then generalists, even though their host plants were still present. Bees that were specialists, parasites, cavity-nesters, and those that participated in weak historic interactions were more likely to be extirpated. Bee species richness visiting forb *C. virginica* did not change between 1891 and 1971, but it declined by over half in the following 40 years, likely due to changes in forested habitat during that time (Burkle 2013). Also in Illinois, Marlin & LaBerge (2001) found 140 bee species in 1970–1972, implying a 32% reduction in biodiversity compared to historical records from the same location 75 years earlier. Only 59 of the 73 prairie-inhabiting bees and 15 of the 27 forest-dwelling bees were found (Marlin and LaBerge 2001). Another study evaluated changes in the distribution of six bumblebee species by comparing historical records with intensive surveys across 382 locations in the United States. Half of the species declined in abundance by as much as 96% of their initial populations in the last 30 years, and their geographical range was reduced between 23 and 87% (Lozier, et al. 2011). In Oklahoma, only 5 of the 10 species of bumblebees that were present in 1949 were found in 2013 after extensive surveys across 21 counties. Additionally, the species *B. variabilis* was presumed extinct (Figueroa and Bergey 2015).

In southern Ontario, bumblebee community composition was compared between 2004–2006 and 1971–1973 at the same sites and this formerly bumblebee diverse region of eastern North America underwent declines in bumblebee species richness, diversity, and relative abundance between these two time periods. Between 1971–1973, 14 bumblebee species were found and between 2004–2006, 11 species were found. Fourteen species found between 1971–1973 were either absent or decreasing in relative abundance between 2004-2006. For example, the rusty patched bumblebee (*B. affinis*) was previously widespread and common but underwent drastic decline and has likely been extirpated throughout much of its range. It was not found during the 2004–2006 surveys. No new species were identified (Colla and Packer 2008).

GENERAL EFFECTS

The ESA regulations define “Effects of the Action” as “all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action but that are not part of the action. A consequence is caused by the proposed action if it would not occur but for the action, and it is reasonably certain to occur. Effects of the action may occur later in time and may include consequences occurring outside the immediate area involved in the action” (50 CFR 402.02). Action “means all activities or programs of any kind authorized, funded, or carried out, in whole or in part, by federal agencies in the United States or upon the high seas” (50 CFR 402.02).

For this Opinion, our analysis of the effects of the proposed registration review of methomyl on listed resources under the Service’s purview is presented first by discussing the General Effects to different taxa groups in the *General Effects* section. The *General Effects* section of this Opinion is divided into several sections and subsections. First, we briefly summarize the anticipated toxicological effects related to the proposed action, including the anticipated general pathways of exposure to listed species taxa groups and their designated critical habitat. Next, in the *Exposure* and *Usage Analysis* sections, we describe specific aspects of methomyl (e.g., chemical properties, applications rates, routes of exposure), its use and usage on the landscape, and how it will impact species and critical habitats based on these properties. We describe those factors that influence exposure and effects and how we chose to incorporate them into our analysis. Theses sections are broadly broken into sections for Terrestrial Animals, Aquatic Animals, and Plants due to fundamental differences in how these groups of species may be exposed, and in turn, respond to methomyl use. We included taxa-specific information that brought meaningful information to the analysis wherever possible.

Toxicological Effects

As described in the BE, methomyl is an N-methylcarbamate insecticide. N-methylcarbamate insecticides act by inhibiting acetylcholinesterase, thereby reducing the degradation of the cholinergic neurotransmitter acetylcholine. As a result, inter-synaptic concentrations of acetylcholine increase as the neurotransmitter accumulates, leading to increased firing of the postsynaptic neurons. This may ultimately lead to convulsions, paralysis, and death of an organism exposed to the chemical. Acetylcholinesterase inhibition is rapidly reversed once exposure to an N-methylcarbamate insecticide has ended. Carbamate toxicity is based on the inhibition of the enzyme acetylcholinesterase, which cleaves the neurotransmitter acetylcholine (AChE). Inhibition of AChE interferes with proper neurotransmission in cholinergic synapses and neuromuscular junctions. This can lead to sublethal effects (e.g., increased respiration, lethargy) and mortality. This mechanism of action (i.e., how a substance produces an effect in an organism) is generally present in animal taxonomic groups (i.e., fish, mammals, birds, amphibians, reptiles, and invertebrates all possess AChE and are subject to the effects of methomyl). Plants also have AChE; however, its mechanism of action is not clearly understood. Figure 5 depicts the Adverse Outcome Pathway for animals exposed to both organophosphates and carbamates as the metabolic pathway is highly conserved for both chemical families.

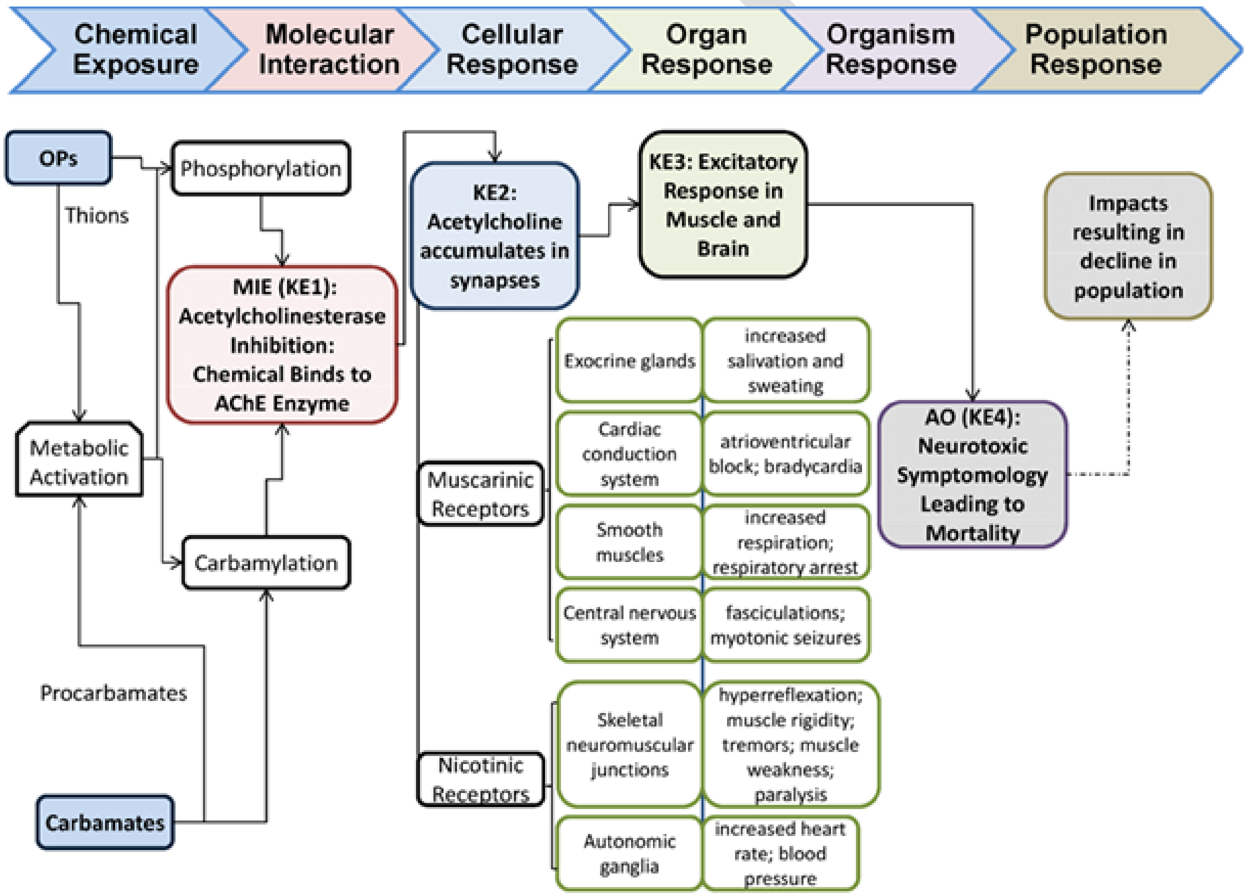

Figure 7. Adverse Outcome Pathway for Acetylcholinesterase Inhibition (the figure is from (Russom, et al. 2014))

Effects by Taxa

The effects of methomyl have been studied extensively in many taxa, particularly in fish and aquatic and terrestrial invertebrates. Studies include acute and chronic laboratory and field studies from both registrant-submitted studies and the open literature, with either technical or formulated methomyl. A technical pesticide is the pure form of a pesticide as it is manufactured prior to being formulated into an end-use product (e.g., wettable powders, granules, emulsifiable concentrates). Toxicity to taxa from exposure to other metabolites of methomyl is not warranted because they are not believed to be of toxicological concern (i.e., methomyl oxime (S-methyl-N-hydroxythioacetimidate), acetonitrile, acetamide, and CO_2).

Laboratory tests are extrapolated to responses we expect to occur in organisms exposed in the field, with the recognition that these types of studies are limited in their ability to recreate natural settings and exposure routes. Most toxicity studies, including those required under FIFRA, are single stressor/single species toxicity tests that are designed to rule out the effects of all other stressors: food is accessible, mates are proximate, predators and competitors are absent, no migration is required, etc. Thus, acute sensitivity of species is determined under conditions that are largely artificial. In addition, these tests are generally not designed to capture and illustrate the consequences of sublethal responses to individual fitness. Sublethal responses, such as decreased olfactory ability, altered schooling behavior for fish, etc., may affect behaviors that cannot adequately be measured in these tests (e.g., feeding, selecting a mate, escaping predation, migrating, etc.) that would otherwise be deleterious to an individual's survival and reproduction (Golden, et al. 2012). In this sense, laboratory toxicity tests designed to be conservative in one manner (constant exposures to chemicals) do not consider many other factors when extrapolated to natural settings. It is not uncommon when reviewing field-based or mesocosm studies to see effects that are not measurable in standard toxicity testing (e.g., changes in community composition due to increased or decreased competition) or effects at concentrations below those which have been identified in lab studies and that may be attributable to the presence of other stressors (e.g., increased or decreased predation).

For population-level analysis, the magnitude of response of individuals to pesticide exposure is an integral piece of toxicological information. The magnitude of response or dose-response relationship describes the range of effects an organism may exhibit at different concentrations of a given chemical. This relationship can be used to assess the responses of individuals within a species, to explore differences among taxonomic levels within a given group to determine sensitivities (e.g., among fish, are Perciformes more sensitive to a given stressor than Salmoniformes or Cypriniformes?), or to explore differences across taxonomic groups (e.g., is a fish more sensitive to a specific stressor than a bird or an insect?). The toxicity data used in Steps 1 and 2 (to inform EPA's BE), as well as other sources of relevant literature considered acceptable for the BE, may be used to determine the magnitude of response in Step 3. Steps 1-3 are previously described in the section *NAS Report and Path Forward* within this opinion.

Toxicity data in this Opinion were divided into ten taxonomic group (i.e., mammals, birds, fish, reptiles, amphibians, aquatic insects and crustaceans, mollusks, terrestrial insects, and plants), which are somewhat similar to those groups assessed in the BE. Depending on availability, we identified dose-response curves, quantitative endpoints, or other qualitative information to assess the expected biological response for multiple endpoints (i.e., direct and indirect effects[11], including mortality, growth, and reproduction) at predicted exposures. Where these analyses have already been performed in the BE, they have been directly carried over.

For each taxonomic group, we selected endpoints for mortality and their accompanying slopes to ensure we captured the sensitivity of the species being assessed. Mortality endpoints include the median lethal dose (LD_{50}) (lethal dose that causes 50% mortality of test subjects), median lethal concentration (LC_{50}) (lethal concentration that causes 50% mortality of test subjects), and hazardous concentration (HC) values (hazardous concentration extrapolated from Species Sensitivity Distribution (SSD) curves). For LD_{50} and LC_{50} data, the most sensitive endpoint was generally chosen. For taxa with SSDs, hazardous concentration 5th percentile (HC_{05}) values (representing the LD_{50} or the LC_{50} of the 5th percentile most sensitive species of the SSD) are generally chosen. Slopes for dose-response curves were derived from information in the BE and were either contained in the studies that generated the toxicity endpoint, contained in one of studies near the HC_{05} in the case of SSDs, or using EPA's default slope of 4.5. Data were also examined to determine if species-specific data were available or if sufficient information existed to group into finer taxonomic categories (e.g., Order or Family level) that may be more or less sensitive to toxicological effects, and therefore more or less susceptible to the impacts of the pesticide. Within the finer taxonomic groups, factors we considered included the number of species, how representative they may be of listed species within the taxa, and the variability of response. We also examined the data for information related to specific life-stages and noted if no data were found.

For all taxonomic groups, we generally assess mortality using a toxicity endpoint and its corresponding slope based on either 1) the most sensitive LD_{50} or LC_{50}, or 2) the HC_{05}, where an SSD is available. While we acknowledge that data do not exist to show that listed species are generally inherently more sensitive to pesticides than non-listed species, in most cases we lack the information to ascertain what that sensitivity may be. By choosing toxicity values that represent the most sensitive of those tested, we are more likely to ensure that we have captured the sensitivity of the species being assessed and not missed potential impacts. The likelihood that we have, in fact, captured the sensitivity of any species is influenced by the number of species tested and the breadth of responses among those species.

We conducted a similar process for each sublethal response endpoint (i.e., growth, behavior, reproduction). For these lines of evidence toxicity data are generally derived from hypotheses-based testing (i.e., effects observed at a limited number of doses). For this reason, rather than constructing dose-response curves, information about the magnitude of response was generally gathered from effects described at different pesticide exposure concentrations. For some

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[11] While our Opinion considers all consequences of the proposed action (per the definition of effects of the action at 50 CFR Part 402.02), the terms "direct" and "indirect" effects were used in EPA's BE, and are used in environmental risk assessment terminology in general, and do not have the same meaning as used in the pre-2019 ESA regulations. As used in the effects analysis section, direct effects to species are those caused by the pesticide itself through dietary, dermal, or inhalation routes of exposure. Indirect effects occur when the pesticide acts on elements of the ecosystem that are required by the species, such as alterations to prey or shelter. Thus, in the effects analysis section, we may sometimes continue to use these terms to link back to the analysis in EPA's BE.

taxonomic groups, a large number of studies were available for one or more response endpoint, and the entire data array presented in the BE were used. For other taxonomic groups, few studies were available to describe effects for one or more response endpoint, and the magnitude of response was wholly based on those data. In other cases, no data were available to describe a response endpoint line of evidence. In these cases, effects were either extrapolated from data from another taxonomic group, or that response was not carried forward in the analysis, as applicable.

A description and analyses of the data available for taxonomic groups are presented below. All data referenced below are from EPA's BE. Citations in descriptions below that begin with Master Record Identifier (MRID) are studies submitted by registrants, and those that begin with "E" are from EPA's ecotoxicology database (ECOTOX). Full citations for these references can be found in EPA's BE.

General Effects to Terrestrial Vertebrates

Terrestrial species may be exposed to pesticides such as methomyl through one or more routes of exposure, including ingestion, dermal absorption, or inhalation. We extrapolate results of laboratory studies to predict the likely effects of each type of exposure to listed species. However, the difficulty in recreating natural settings and exposure routes in the laboratory limits the relevance of these studies when assessing affects to species in their natural environment. Some of these limitations, especially for terrestrial vertebrates, are discussed below, followed by a description of the available data for each taxonomic group.

Mortality

For terrestrial vertebrates, most laboratory studies measure effects of toxicity from the ingestion route of exposure. Researchers provide test subjects with contaminated food (concentration based, for derivation of LC_{50} values) or administer a single dose through oral gavage or injection (dose-based, for derivation of LD_{50} values). Generally, only orally administered routes are considered to be environmentally relevant and directly comparable to estimated environmental concentrations, as the route of transport in the body is equivalent to how individuals would be exposed to these concentrations in the wild. However, the intraperitoneal exposure route has been demonstrated to have an absorption route with a similar circulatory pathway (initial absorption into the portal system) as ingested substances for organic compounds and may be the type of exposure route selected for toxicity testing (for derivation of LD_{50} values) to avoid potential regurgitation of the administered dose in certain cases (Lukas, Brindle and Greengard 1971). Both dietary endpoints (LC_{50} values) and dose-based endpoints (e.g., LD_{50} values) produced from these tests are derived in a manner that is reflective of certain aspects of how species are likely to be exposed in the wild. Both assess the sensitivity of species to potentially toxic food sources only, but not other routes of exposure (i.e., dermal or inhalation) nor other methods of ingestion such as drinking water. The LC_{50} studies provide an estimate of toxicity based on constant exposure to a set concentration of pesticide in food over a series of days, while the LD_{50} studies provide an estimate of toxicity based on a single potentially lethal exposure. Both these methods capture a subset of conditions in which terrestrial species may be exposed to pesticides. Species in some feeding guilds such as granivores or insectivores are likely to feed and ingest pesticide throughout the day if confined to a contaminated area, while predatory or scavenging species may be exposed to a dose of a pesticide from an exposed carcass and not feed again for one or more days. However, listed species may undertake a large variety of feeding styles beyond those emulated in toxicity testing. Highly mobile species may receive intermittent doses of pesticides from feeding at different locations with varying levels of contamination. Secondary predators may get a large dose of pesticide that has not been fully digested nor on the surface of prey but remains in the gastrointestinal tract in its parent form (i.e., unmetabolized) (Hill and Mendenhall 1980). Frequency or types of dietary items vary throughout the year, depending on availability, needs for migration, or reproduction. Long-distance migrators such as the red knot may gorge feed at stopover locations, then travel long distances on food stores from these events.

We recognize that it is not possible to emulate all exposure regimes or recreate all stressors in a laboratory setting. We acknowledge that current toxicity testing can provide some estimate of the sensitivity of species for a given exposure route and source. For the assessment of acute toxicity, where both dose-based and concentration-based data exist, while we consider all data, we often rely on the results of dose-based exposures (i.e., LD_{50}s) to produce an estimate of mortality for birds and mammals. In many cases, data exist for a greater number of species within these taxonomic groups for dose-based toxicity testing than for concentration-based testing, increasing the likelihood of including data from species with a greater range of sensitivities. This helps to reduce the uncertainty that we have captured the range of sensitivity of listed species, as often data exist for only a small number of species (e.g., as few as six for FIFRA-required studies) that must be extrapolated across all listed species representing varying taxonomic groups and ecological guilds. In many cases, these data vary widely, even within taxonomic groups and for individuals of the same species, suggesting that sensitivity is not easily captured by a small number of species. Dose-based studies are also coupled with taxa-specific conversion factors that have been generated from available data to convert acute mortality values across species based on body weight and food ingestion rate, increasing their accuracy when extrapolating to species with different physiological characteristics. Dose-based studies often, but not always, result in effects at lower concentrations for these taxa. This is likely attributable to several factors, including the greater number of species available as surrogates. This helps to account for some of the conservatism that is lost when extrapolating to field conditions, and thus provide a more accurate representation of the breadth of effects to species being assessed in the Opinion.

For reptiles and amphibians, we often have greater uncertainty in predicting effects than other taxonomic groups. As there is no testing requirement under FIFRA for these taxa, data from the open literature are often lacking, and taxa-specific conversion factors are generally derived from a smaller breadth of species than for birds and mammals. Where taxa-specific data are lacking to predict effects to these species, we use toxicity data from birds to predict effects, as we consider amphibians and reptiles to be more closely related to birds than other broad taxa groups (such as mammals, arthropods, etc.). While there is notable uncertainty in this approach, we rely on the conservative nature of endpoint selection (e.g., most sensitive species, lowest endpoint, use of dose-based studies) to adequately capture the sensitivity of these taxa.

Sublethal endpoints

For sublethal endpoints, while all data are considered, analyses often rely on concentration-based studies. Most studies that are designed to examine sublethal effects such as growth, behavior, and reproduction are chronic dietary studies. Many endpoints carried over into our analysis are derived from registrant-submitted studies that examine these endpoints as part of long-term reproduction studies (e.g., 20 weeks for birds). Since these studies incorporate many aspects of the reproductive cycle (e.g., litter size, copulation, egg formation, parental care, growth of young), one or more responses to pesticide exposure may be incorporated into ultimate effects to reproduction. In this way, many parts of the reproductive cycle are examined, but it is often difficult to tease out specific effects or which aspect of the reproductive process was compromised. For these types of studies, we consider the nature and magnitude of effects at test concentrations as well as in the No Observed Adverse Effect Concentration (NOAEC). In some cases, effects may be observed at the concentration identified as the NOAEC, but they are not statistically different from controls due to test design and sensitivity. While we cannot assign these effects to the test substance in these cases, we can consider these observations in the larger context of the study. In all cases, it is important to consider effects that could occur in the span of concentrations between the NOAEC and the Lowest Observed Adverse Effect Concentration (LOAEC), especially when there are high effects at the LOAEC.

Effects to Birds

For birds, toxicity data for mortality were available from 10 references representing 15 endpoints and six species (zebra finch, Japanese quail, mallard/pekin duck, ring-necked pheasant, northern bobwhite quail, and domestic chicken). Available dose-based mortality data (LC_{50}, LOAEL and NR-LETH) are available for 5 species of birds (zebra finch, mallard duck, ring-necked pheasant, northern bobwhite quail, and domestic chicken) with a reported mortality effect range from 2.03 to 60 mg/kg-bw. LC_{50} data are available for four species of birds (Northern bobwhite quail, mallard/pekin duck, ring-necked pheasant, and Japanese quail) with a reported mortality effect range from 1,100 to 5,080 mg/kg-diet. The endpoints considered for mortality are included in the tables below.

Mortality: Dose-based oral exposure

The available bird LD_{50} toxicity data for methomyl represents five species over three taxonomic Orders (Anseriformes, Galliformes, Passeriformes) (Table 8 and Table 9). Reported LD_{50}'s range from 2.03 mg/kg-bw (zebra finch) to 41 mg/kg-bw (domestic chicken). Given the small number of species studied, the EPA was not able to calculate a species sensitivity distribution.

The most sensitive LD_{50} observed was reported by a study that exposed zebra finch to methomyl dissolved in deionized water over a 14-day exposure period. All deaths occurred within 24 hours, with 20% mortality at the 1.36 mg/kg-bw treatment and 100% mortality at the 4 mg/kg-bw treatment.

Table 8. Available Dose-Based Mortality Data (oral) for Birds Exposed to Methomyl

Scientific Name	Common Name	LD_{50} or other endpoint (mg/kg-bw)	Duration (days)	MRID/ECOTOX ref #
Taeniopygia guttata	Zebra Finch	2.03	14	MRID 49054101

Phasianus colchicus	Ring-Necked Pheasant	15	14	MRID 00160000/ E50386
Anas platyrhynchos	Mallard Duck	15.9	14	MRID 00160000/ E50386
Colinus virginianus	Northern Bobwhite Quail	24.2	14	MRID 00161886
Gallus domesticus	Domestic Chicken	41	NR	E74129
Anas platyrhynchos	Mallard Duck	LOAEL = 7.5	30	MRID 00160000/ E50386

Table 9. Available Dietary-Based Mortality Data for Birds Exposed to Methomyl.

Scientific Name	**Common Name**	**LC_{50} (mg/kg-diet)**	**Duration (days)**	**MRID/ECOTOX ref #**
Colinus virginianus	Northern Bobwhite Quail	1100	8	MRID 00022923/ E35243
Anas platyrhynchos	Pekin Duck	1890	NR[12]	MRID 00007820
Phasianus colchicus	Ring-Necked Pheasant	1975	8	MRID 00022923/ E35243
Anas platyrhynchos	Mallard Duck	2883	8	MRID 00022923/ E35243
Coturnix japonica	Japanese Quail	3436	8	MRID 40910905/ E50181
Anas platyrhynchos	Mallard Duck	3602	8	MRID 45299802
Colinus virginianus	Bobwhite Quail	3680	NR	MRID 00007820
Colinus virginianus	Northern Bobwhite Quail	5080	8	MRID 45299801

Mortality: Dietary-based oral exposure

Available dietary based LC_{50} studies cover five species from two orders of birds (Galliformes and Anseriformes). Reported LC_{50}'s range from 1,100-5,080 mg/kg-bw. The study reporting the

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most sensitive LC_{50} exposed bobwhite quail to methomyl in food at four dietary concentrations over eight days.

Reproduction

Available data on the effects of methomyl to bird reproduction include two references representing four endpoints and two species. No oral dose-based studies are available that captured reproductive endpoints. Dietary-based studies report effects at exposure levels ranging from 150-1,120 mg/kg-diet.

In a study exposing bobwhite quail to methomyl, researchers identified the lowest no adverse effect level (NOAEL) as 150 mg/kg-diet. In the same study, researchers observed a 35% reduction in the number of eggs laid per hen and a 36% reduction in eggs set per hen at 458 mg/kg-diet (MRID 41898602, (Beavers, et al. 1991). Additionally, hens exposed to methomyl at 458 mg/kg-diet showed reduced body weight; however, this effect was not statistically significant. It should be noted that there was an error in the premix diet, and the test treatment level that was supposed to receive 50 ppm initially received 4-weeks treatment at 150 ppm. This was corrected and continued with the correct treatment level for the duration of the study. The statistical analysis was completed with and without the inclusion of the 50 ppm treatment level, and the inclusion of the data did not impact the data analysis or NOAEL/LOAEL determinations.

Growth

Available data on the effects of methomyl to bird growth include two references representing two endpoints and two species. No oral dose-based studies are available that captured growth endpoints. For dietary studies, the range of reported growth effects are 458 to 1,120 mg/kg-diet. No studies reported any adverse effects to growth below 150 mg/kg-diet. The most sensitive endpoint reported in these studies was at 458 mg/kg-diet (based on mean-measured test concentrations – nominal concentrations were 150 and 500 mg/kg-diet), and a maximum acceptable toxicant concentration (MATC) of 262 based on a dose responsive weight loss reduction in female body weight in the bobwhite quail (MRID 41898602).

Incident Reports

As of January 22, 2020, there were nine bird incident reports in EPA's Incident Data System with a certainty index of 'possible,' 'probable,' or 'highly probable' (Table 10). Of these nine incidents, two are from a registered use, four are from misuse (either accidental or intentional), and in three of the incidents, the legality of use was undetermined (see Table 2-18 and Attachement 2-2 in the BE, for details). The following discussion only includes those incident reports with a certainty index of 'possible,' 'probable,' or 'highly probable' and a legality classification of 'registered' and 'undetermined' (the incidents that were caused by a misuse are not reported further). There were two additional bird incidents attributed to methomyl in the analog identification methodology or AIM database; however, both these incidents were from misuse, 'abuse' of the product, and therefore are not reported further.

Table 10. Summary of reported bird incidents involving methomyl provided by the EPA.

INCIDENT NUMBER	YEAR	CHEMICAL(S) INVOLVED (PC CODE)	CERTAINTY INDEX (for methomyl)	STATE	LEGALITY (for methomyl)	USE SITE	SPECIES AFFECTED	DISTANCE	EFFECT/ MAGNITUDE	PRODUCT
I006382-001	1989	Methomyl (090301)	Probable	France	Registered use (in France)	Cabbage	Finches	In the field the day after application	At least 52 bull finches and 6 gold finches	Lannate 20L
I006382-002	1992	Methomyl (090301), Mancozeb (014504)	Probable	France	Registered use (in France)	Cabbage	Finches (*i.e.*, green finches, and goldfinches) and linnets	Unknown	Death of 35 birds, and intoxication of 31 birds; after birds were observed drinking dew from cabbage field the morning of application. Detection of 0.018 ppm methomyl in a dead bird.	Lannate 20L
I018980-010	2004	Methomyl (090301), Oxamyl (103801)	Possible	VI, UK	Undetermined	*No data*	13 laughing gulls (*Larus articilla*) & 1 cattle egret (*Bubulcus ibis*)	Unknown	Mortality of 14 birds total; the cause was toxicosis by methomyl and oxamyl.	Methomyl
I021455-003	2009	Methomyl (090301)	Highly probable	FL	Undetermined	N/R	Vultures (*Cathartidae*) & Virginia opossum (*Didelphis marsupialis*)	Unknown	31 vultures and 3 opossums found sick or dead. Diagnostic evaluation found methomyl toxicosis. 82%	Methomyl

INCIDENT NUMBER	**YEAR**	**CHEMICAL(S) INVOLVED (PC CODE)**	**CERTAINTY INDEX (for methomyl)**	**STATE**	**LEGALITY (for methomyl)**	**USE SITE**	**SPECIES AFFECTED**	**DISTANCE**	**EFFECT/ MAGNITUDE**	**PRODUCT**
									ChE inhibition with complete reversal upon incubation. Report states no bait or human presence was found.	
I024528-002	2010	Methomyl (090301)	Probable	CA	Undetermined	River	Blackbird (*Icteridae*), Dove (*Columbina* sp.) and finch (*Fringillidae*)	On field	*Approx.* 60 birds (mourning doves, finches and blackbirds) were found dead in a strawberry field. It was suggested that the seed may have been poisoned with methomyl. The seed found in the crop contents of dead birds detected 0.00326 ppm and 0.0013 ppm of methomyl.	Methomyl

The dates of the bird incident reports that have a certainty index of 'possible,' 'probable,' or 'highly probable' range from 1989 to 2016. The bird incident reports involve a variety of bird species (e.g., songbirds, doves, and raptors). In most of the known incidents, the use site is not reported or is unknown. For those incidents that do report a use site, the incidents were associated with the following use sites: cabbage (2); and an agricultural field (1). The methomyl product involved in the incidents is not reported or not specified beyond 'Lannate 20L' in most of the incidents. In most of the incident reports, methomyl was the only pesticide noted in the report. There are, however, two incident reports that involve at least one pesticide in addition to methomyl.

In addition to the terrestrial incident reports available in EPA's Incident Data System, there have also been a total of 13 aggregate wildlife incidents. Of these 13, seven are associated with active registrations (six involve products either no longer registered or no registration numbers reported) (Table 11).

Table 11. Summary of aggregate wildlife incidents provided by the EPA.

PRODUCT REGISTRATION NUMBER	PRODUCT NAME	NUMBER OF AGGREGATE WILDLIFE INCIDENTS	YEAR(S)
000352-00342	DUPONT LANNATE SP INSECTICIDE	1	2003
002724-00274	GOLDEN MALRIN RF-128 FLY KILLER	6	2011, 2012, 2013, 2017

Since 1998, incidents that are allowed to be reported aggregately by registrants [under FIFRA 6(a)(2)] include those that are associated with an alleged effect to wildlife (birds, mammals, or fish) without differentiation between species or terrestrial and aquatic environments. Typically, the only information available for aggregate incidents is the date (i.e., the quarter) that the incident(s) occurred, the number of aggregate incidents that occurred in the quarter, and the PC code of the pesticide and the registration number of the product involved in the incident. Because of the limited amount of data available on aggregate incidents it is not possible to assign certainty indices or legality of use classifications to the specific incidents. Therefore, the incidents associated with currently registered products are assumed to be from registered uses unless additional information becomes available to support a change in that assumption.

Effects to Reptiles

No toxicity data are available for reptiles exposed to methomyl. The available toxicity data and thresholds for birds are used as a surrogate for reptiles. There is notable uncertainty in using birds as surrogates for reptiles as it is assumed that they will have similar responses to methomyl.

Effects to Terrestrial Amphibians

No toxicity data are available for terrestrial-phase amphibians exposed to methomyl. The available toxicity data and thresholds for birds are used as a surrogate for amphibians. There is notable uncertainty in using birds as surrogates for amphibians as it is assumed that they will have similar responses to methomyl.

Effects to Mammals

The effects of methomyl on mammals have been studied extensively. The EPA excluded mammalian studies if they were considered invalid or not associated with an environmentally relevant exposure route. Acute toxicity data was only available for three species and did not allow for a calculation of a species sensitivity distribution. As such, thresholds are based on the most sensitive lethal and sublethal effects identified among registrant-submitted studies and open literature in the ECOTOX database.

Mortality: Dose-based oral exposure:

All values for any reported mortality effect range from 7.14 to 5,367 mg/kg-bw (MRID 48226104 to MRID 43692201, respectively), which include four species of mammals (house mouse, various genetic lines of rats, New Zealand white rabbit, and mule deer), representing three orders (Rodentia, Lagomorpha, Artiodactyla) (Table 12).

The lowest LD_{50} value reported for methomyl was 7.14 (6.22-8.19) mg/kg-bw for female Harlan Sprague-Dawley albino rats exposed for 14 days (MRID 48226104, (Sobotka 1996)). Researchers exposed rats to the formulation ROTAM 90SP of methomyl (90% a.i.) by oral gavage with doses ranging from 5.0 to 25.0 mg/kg-bw. All deaths occurred within the first two hours after dosing, and there were no deaths in the 5 and 8 mg/kg-bw dose level females/males, respectively. However, the study reported deaths at all other test levels (6.5/17 mg/kg-bw or greater for females/males, respectively). All animals (females/males) in all dose groups showed signs of toxicity (except those dying within the first hour of dosing), including piloerection, activity decrease, salivation, body tremors, sensitivity to sound, gasping, rapid breathing, polyuria, ptosis and red-stained muzzles. Survivors recovered by day 8. The gross necropsy for rats observed matted muzzles, clear or white liquid in stomachs, orange gel in small intestines, and/or green paste in large intestines. However, surviving rats had no observable abnormalities.

Table 12. Available methomyl mortality data in mammals.

Scientific Name	Common Name	LD50 (mg/kg-bw)	Duration (days)	Reference
Oryctolagus cuniculus	New Zealand White Rabbit	6	29	MRID 00131257
Mus musculus	House Mouse	0.9	30	E167164
Rattus norvegicus	Norway Rat	2.3	NA	E104027

Scientific Name	Common Name	LD50 (mg/kg-bw)	Duration (days)	Reference
Rattus norvegicus	Norway Rat	7	7	E74712
Rattus norvegicus	Norway Rat	14	14	E75301
Rattus norvegicus	Norway Rat	5.1	4	E5395
Rattus norvegicus	Norway Rat	25	90	MRID 00007190/E5395
Mus musculus	House Mouse	8.49	24	E72485
Rattus norvegicus	Harlan Sprague-Dawley rats	7.14	14	MRID 48226104
Rattus norvegicus	Harlan Sprague-Dawley rats	14.2	14	MRID 48226104
Rattus norvegicus	Rat	17	14	MRID 00009227
Rattus norvegicus	Rat	24	14	MRID 00009227
Rattus norvegicus	Rat	49	14	MRID 44181302
Rattus norvegicus	Sprague-Dawley albino rats	51	1	MRID 48217706
Rattus norvegicus	Norway Rat	22.68	14	E75301
Rattus norvegicus	Rat	89	14	MRID 44181302
Rattus norvegicus	Sprague-Dawley albino rats	102.7	14	MRID 48223904
Rattus norvegicus	Norway Rat	23.8	14	E75301
Rattus norvegicus	Sprague-Dawley albino rats	354	14	MRID 45177003
Rattus norvegicus	Sprague-Dawley albino rats	500	14	MRID 45177003

Scientific Name	Common Name	LD50 (mg/kg-bw)	Duration (days)	Reference
Rattus norvegicus	Harlan Sprague-Dawley rats	1140	14	MRID 44933202
Rattus norvegicus	Harlan Sprague-Dawley rats	1720	14	MRID 44933202
Rattus norvegicus	Sprague-Dawley rats	5367	14	MRID 43692201
Rattus norvegicus	Norway Rat	24.75	14	E74538
Rattus norvegicus	Rat	30	14	MRID 42140101
Rattus norvegicus	Rat	34	14	MRID 42140101
Rattus norvegicus	Norway Rat	39.6	14	E74538
Odocoileus hemionus ssp. hemionus	Mule Deer	11	14	E50386
Odocoileus hemionus ssp. hemionus	Mule Deer	22	14	E50386
Rattus norvegicus	Norway Rat	0.25		MRID 44487501
Rattus norvegicus	Norway Rat	94.9	13	MRID 44666201
Rattus norvegicus	Norway Rat	113	13	MRID 44666202

Growth

Growth endpoints range from 2.0 mg/kg-bw to 30 mg/kg-bw. Researchers observed a 73% decrease in body weight gain in female rats during days 2-8 at 2.0 mg/kg-bw. The highest growth effect endpoint reported is decreased body weight in female rats at 113 mg/kg-bw (Table 13).

Table 13. Available data on sublethal effects to growth of methomyl in mammals.

Scientific Name	Common Name	NOAEL (mg/kg- bw)	LOAEL (mg/kg- bw)	Reference
Rattus norvegicus	Norway Rat	1.96	7.84	E73602

Scientific Name	Common Name	NOAEL (mg/kg- bw)	LOAEL (mg/kg- bw)	Reference
Rattus norvegicus	Norway Rat	6.25	12.5	MRID 00007190/E5395
Rattus norvegicus	Charles River CD rats	5	20	MRID 00078361
Rattus norvegicus	Charles River CD rats	9.4	33.9	MRID 00008621
Rattus norvegicus	Rat	9.4	94.9	MRID 44666201
Rattus norvegicus	Rat	11.2	113	MRID 44666201
Rattus norvegicus	Rat	NR	2.0	MRID 44487501
Mus musculus	House Mouse	NR	4	E74311
Rattus norvegicus	Norway Rat	NR	6	E74712
Rattus norvegicus	Norway Rat	7.84	NR	E73602
Rattus norvegicus	Norway Rat	8	NR	E74712
Rattus norvegicus	Norway Rat	8	NR	E74712
Rattus norvegicus	Norway Rat	8	NR	E74712
Rattus norvegicus	Norway Rat	8	NR	E74712
Rattus norvegicus	Norway Rat	8	NR	E74712
Rattus norvegicus	Norway Rat	8	NR	E74712
Rattus norvegicus	Norway Rat	8	NR	E74712
Rattus norvegicus	Norway Rat	8	NR	E74712
Rattus norvegicus	Norway Rat	8	NR	E74712
Rattus norvegicus	Norway Rat	8	NR	E74712
Rattus norvegicus	Norway Rat	200	NR	E75289

Scientific Name	Common Name	NOAEL (mg/kg- bw)	LOAEL (mg/kg- bw)	Reference
Rattus norvegicus	Norway Rat	200	NR	E75289
Rattus norvegicus	Charles River CD rats	33.9	NR	MRID 00008621
Rattus norvegicus	Norway Rat	200	NR	E74347
Rattus norvegicus	Norway Rat	NR	10.8	E74539
Rattus norvegicus	Norway Rat	NR	10.8	E74539
Rattus norvegicus	Norway Rat	NR	12.9	E74539
Rattus norvegicus	Rat	NR	30	MRID 43250701 & 43769401
Oryctolagus cuniculus	New Zealand White Rabbit	16		MRID 00131257
Rattus norvegicus	Norway Rat	0.75	2	MRID 44487501

NR = not reported

Reproduction

The lowest no adverse effect level observed in mammalian toxicity studies is 3.75 mg/kg-bw. The lowest level of exposure where an adverse effect to reproduction was observed was 30 mg/kg-bw, which caused a decrease in the number of live pups (MRID 43250701 & 43769401; (Lu 1983, Hurtt 1995). The reported effects endpoints in the reproduction group tend to be similarly or slightly less sensitive than other major effects group (Table 14).

Table 14. Available data on sublethal effects of methomyl to mammal reproduction.

Genus	Species	Scientific Name	Common Name	NOAEL	LOAEL	Reference
Rattus	norvegicus	*Rattus norvegicus*	Rat	3.75	30	43250701 43769401

Incident Reports

As of January 22, 2020, there are seven mammal incident reports in the EPA's Incident Data System with a certainty index of 'possible,' 'probable' or 'highly probable' (Table 15). Of these seven incidents, four are from misuse (either accidental or intentional), and in three of the incidents, the legality of use was undetermined. The following discussion only includes those incident reports with a certainty index of 'possible,' 'probable,' or 'highly probable,' and a legality classification of 'registered' and 'undetermined' (the incidents that were caused by a misuse are not reported further).

Table 15. Summary of incident reports of mammals involving methomyl.

NUMBER	YEAR	CHEMICAL INVOLVED (PC CODE)	CERTAINTY INDEX	State	LEGALITY	USE SITE	SPECIES	DISTANCE	EFFECT/ MAGNITUDE	PRODUCT
I021455-003	2009	Methomyl (090301	Highly probable	FL	Undetermined	N/R	Vultures (*Cathartidae*) & Virginia opossum (*Didelphis marsupialis*)	Unknown	31 vultures & 3 opossums found sick or dea Diagnostic evaluation found methomyl toxicosis. 82% ChE inhibition with complete reversal upon incubation. Report states no bait or human presence was found.	Unknown
I024767-006	2007	Methomyl (090301)	Highly probable	MI	Undetermined	Unknown	Squirrel	N/R	3 squirrels found dead in a backyard. Diagnosis was poisoning by methomyl	Unknown
I024767-008	2012	Methomyl (090301), (Z)-9-tricosene (103201)	Probable	OH	Undetermined	Residential	Cat	Unknown	Death of a neighborhood cat	Golden Marlin

The dates of the mammalian incident reports range from 2007 to 2016. The mammal incident reports involve a variety of different kinds of mammals (e.g., opossums, cats, raccoons, and squirrels). In most of the known incidents, the use site is not reported or is unknown. The methomyl product involved in the incidents is not reported nor specified beyond 'Golden Marlin' in one of the reported incidents. In most of the incident reports, methomyl was the only pesticide noted in the report. There was, however, one mammalian incident report that involved at least one pesticide in addition to methomyl.

In addition to the terrestrial incident reports available in EPA's Incident Data System, there have also been a total of 13 aggregate wildlife incidents. Of these 13, seven are associated with active registrations (six involve products either no longer registered or no registration numbers reported) (refer to Table 10 in bird incident report section).

Effects to Terrestrial Invertebrates

The terrestrial invertebrates taxonomic group was designated in the BE and described as all invertebrates with a terrestrial lifecycle. Based on available toxicity data, the Service further divided the terrestrial invertebrates into two taxonomic groups in this Opinion. The first group, terrestrial insects and arachnids, includes all insects with a terrestrial or partial terrestrial lifecycle, spiders, and their relatives. The second group is terrestrial snails. We more narrowly apply the terrestrial invertebrate data from the BE based on insect toxicity data to terrestrial insects and discuss toxicity data to terrestrial snails below using data specifically for terrestrial snails.

Insects and Arachnids

Given the wide breadth of taxonomic Orders within the terrestrial insect and arachnid category, assumptions were made based on the known effects of the action to this wide array of species. First, we assumed that the toxicity data available were applicable to only terrestrial or partially terrestrial insects, and spiders and their relatives within this category based on data from the available literature. Methomyl is an insecticide used to kill a broad range of insects. As an insecticide, methomyl's effects on terrestrial insects have been well documented in the literature. Most available studies have focused on mortality endpoints; however, there are also data available for describing sublethal effects, including those related to growth, behavior, and reproduction. Similar to our approach for other taxa (i.e., mammals, birds) assessed for this Opinion, we chose the most sensitive LD_{50} (LD_{50} from a study on Hymenoptera) to describe direct effects to terrestrial insects and arachnids.

The toxicity data in the BE relied upon the all terrestrial invertebrate most sensitive endpoint EC_{50} of 4.75 mg/kg-soil. This value is based on a 37-day earthworm study where organisms were exposed to methomyl in a soil mixture. However, the Service is instead relying on a 7-d contact exposure study in Hymenoptera with an LD_{50} value of 0.068 µg a.i./bee which, when taking into account the body weight (0.128g) of the test species, converts to 0.53 mg a.i./kg-bw to address toxicity to terrestrial invertebrates. We feel this study by (Mansour and Al-Jalili 1985) more appropriately addresses impacts to the terrestrial or partially terrestrial insects as well as spiders and their relatives. We also chose this endpoint for the following reasons: limited toxicity data for some invertebrate groups (i.e., families, sub-families), which may not be sufficient to explain the range of effects (or sensitivity) to all the listed species within that taxa group; insufficient data for taxonomic groups to construct an SSD; a wide range of within-Order variability across a limited number of studies; insufficient data reported for a particular unit of exposure; and, in some cases, concentration units that could not be converted to units comparable to the exposure units this taxa group would see on the landscape. EPA also demonstrates in the data array in their BE, that this value is most protective of a wide range of orders and families of terrestrial invertebrates.

Terrestrial Snails

For the toxicological analysis for terrestrial snails, we find the open literature data available on methomyl exposure in terrestrial snails more appropriate to address the effects of methomyl on terrestrial snails than the contact exposure study described above for the honey bee. The exposure routes described in these studies are also a more appropriate means by which terrestrial snails could be exposed to methomyl (contact and dietary).

We use the most sensitive 72-h LC_{50} value of 1,467 ppm from a study by (Bashandy and Raddy 2021) using the terrestrial snail species *Eobania vermiculata*. Several open literature studies for methomyl assess exposure to terrestrial snails (Bashandy and Raddy 2021, Eshra 2014, Hussein, et al. 1999, Radwan, et al. 2008, Khalil 2016). These data had various units of measurements for the endpoints studied (µg/snail, ppm, etc.). Despite the various endpoints, terrestrial snails were relatively tolerant of methomyl exposure across these studies. While there are few methomyl studies to use for the terrestrial snail toxicity endpoint, we feel it is more appropriate than using related carbamate data from aquatic snails (we only use related carbamate data for aquatic snails; see discussion in the *Effects to Aquatic Invertebrates* section below). The route of exposure would be different for terrestrial snails (dietary or contact for terrestrial snails) than for aquatic snails (contact) and the value used for aquatic snails is based on an SSD using all aquatic snail data combined with other aquatic mollusks. We also feel this endpoint is appropriate for terrestrial snails as it verifies that snails in general are not sensitive to methomyl exposure and the endpoints for both terrestial and aquatic snails are within the same order of magnitude.

Using a more appropriate surrogate species, we do not expect any mortality to occur, as even the highest estimated environmental concentrations are much lower than the LC_{50} reported in available studies of these terrestrial snails. Effects to the food base (e.g., algae, plant leaves or roots, lichen, detritus) are likely to be minimal and impacts to the food base will not have a discernable effect at the species level.

Given that terrestrial insects are the target organism for the effects of methomyl, species in this taxonomic group are likely to die prior to any sublethal effects occurring. As such, sublethal effects were not pursued for this analysis at this time, although in some instances we list this information below when it was available. The mortality toxicity data we used to assess the effects of methomyl are provided below, along with a discussion of the available incident reports for methomyl and terrestrial invertebrates as also described in the BE.

The available toxicity data for terrestrial invertebrates are based on experimentally determined endpoints for methomyl based on varying durations, exposure routes, and study designs. All data referenced below are from the Effects Characterization (Chapter 2 and appendices) of the BE.

Mortality (mg/kg-bw)

The majority of the toxicity data available for methomyl and terrestrial invertebrates involve mortality endpoints. In all cases, mortality is the most sensitive endpoint available for the different environmentally relevant exposure units. EPA based the toxicity values and data arrays in the BE on endpoints expressed in, or readily converted to, the following exposure units: milligram per kilogram body weight (mg/kg-bw), microgram per organism (e.g., µg/bee or µg/larvae), milligram per kilogram of soil (mg/kg soil), or microgram per gram dry food (µg/g diet).

For the exposure unit mg/kg-bw, as described briefly above, the most sensitive endpoint available for terrestrial invertebrates is an LD_{50} value of 0.0608 mg a.i./bee for the honey bee (*Apis mellifera*) (E67983), converted to 0.53 mg a.i./kg-bw based on the standard body weight of the honey bee (0.128 g). In this study, clover fields were sprayed with five different concentrations of methomyl plus a solvent control, then flower samples were collected and mixed with acetone. This mixture was then extracted and applied to adult 7-day old worker bees. All data were corrected for purity (90% methomyl). One µl of the test solutions were applied to the mediodorsal thoracic surface of each bee with a microapplicator syringe. Results are in Table 2-26 in the BE).

Incident Reports for Terrestrial Invertebrates

In their BE (Table 2-28), EPA reported two terrestrial invertebrate incident reports (both for bees) in EPA's Incident Data System with a certainty index of "possible," "probable," or "highly probable," and a legality classification of 'registered' and 'undetermined' (the incidents that were caused by a misuse are not reported further) (Table 16). Of these two incidents, the legality of use was undetermined. The dates of the bee-kill incident reports were about 2014 and ranged from approximately 12 dead bees to "thousands." Both of these incidents are classified as undetermined legality, of probable certainty, and are related to each other. A bee keeper provided a bee kill incident report from the Massachusetts Department of Agriculture and Resources. Methomyl residues were detected in the dead bees at levels of 100 ppb but lambda-cyhalothrin (a pyrethroid pesticide) from Warrior (product name of the lambda-cyhalothrin pesticide) was not detected (likely below the level of detection, 53 ppb). Overall, the available incident data indicate that exposure pathways for methomyl are complete (can be traced from the source to the organism impacted) and that exposure levels are sufficient to result in field-observable effects.

Table 16. Summary of incident reports of terrestrial invertebrates involving methomyl.; Table 2-28 from the BE.

INCIDENT NUMBER	YEAR	CHEMICAL(S) INVOLVED (PC CODE)	CERTAINTY INDEX (for methomyl)	STATE	LEGALITY (for methomyl)	USE SITE	SPECIES AFFECTED	DISTANCE	EFFECT/ MAGNITUDE	PRODUCT
I026963-002	2014	Methomyl (090301) Lambda-cyhalothrin (128897)	Probable	MA	Undetermined	Residential	Honey bee (*Apis mellifera*)	Bee keeper is convinced pesticide applied to sweet corn in vicinity is responsible for death of bees.	Thousands	This incident is related to I026976-001; a bee keeper provided a bee kill incident report from the MA Dept. of Agriculture and Resources that is applicable to both reports (I026976-001 and I026963-002); methomyl was detected in the dead bees but lambda-cyhalothrin from Warrior was not.
I026976-001	2014	Methomyl (090301)	Probable	MA	Undetermined	Agricultural area	Honey bee (*Apis mellifera*)	*Approx*. a dozen bees were observed dying in the vicinity of application	Mortality/12	Lannate LV. Bees were collected and delivered to the Massachusetts Pesticide Analytical Lab (MAPL) on July 23, 2014. Results were positive for methomyl (100ppb) and no detection for cyhalothrin (active ingredient used by a local farmer; which was likely below the detection limit of 53 ppb. This incident is related to I026963-002; a bee keeper provided a bee kill incident report from the MA Dept. of Agriculture and Resources that is applicable to both reports (I026976-001 and I026963-002); methomyl was detected in the dead bees but lambda-cyhalothrin from Warrior was not.

General Effects to Aquatic Species

The breadth of toxicity data, in terms of species and taxa representation, available for our effects assessment for listed species (from the BE) was based on studies generated by registrants as well as open literature studies and government reports retrieved through ECOTOX. As a result, there tends to be an abundance of data for taxa that are more commonly tested or required for regulatory purposes (i.e., fish, aquatic insects, and aquatic crustaceans), compared to less well-studied taxa, such as mollusks (including mussels and aquatic snails) and amphibians. Similarly, within taxa, there may be numerous studies for common aquatic test species, such as rainbow trout (*Oncorhynchus mykiss*), fathead minnow (*Pimephales promelas*), bluegill (*Lepomis macrochirus*), sheepshead minnow (*Cyprinodon variegatus variegatus*), water flea (*Daphnia* spp.), or the amphipod *Hyalella azteca*, but fewer studies for species representing other genera, families, or orders. As a result, the taxa for which toxicity data are available may or may not be strong surrogates for listed species. Considering the high variability in toxicity values between species for some taxa groups (e.g., two orders of magnitude difference between the highest and lowest fish acute mortality data or LC_{50} values), it is important that we take this uncertainty into account when assessing risks to listed species.

Listed aquatic species that may be affected by methomyl in aquatic habitats include fish, amphibians (aquatic phases), and various taxa of aquatic invertebrates (i.e., aquatic insects, crustaceans, and mollusks). For those species that are exclusively aquatic, all life stages may be affected by exposure to methomyl in water. Some species of aquatic insects (e.g., dragonflies, damselflies, and stoneflies) and amphibians (e.g., frogs, toads, and some salamanders) have both aquatic and terrestrial life stages and may therefore be affected by exposures in either aquatic or terrestrial habitats, or both. Certain species also have obligate relationships with other species. For example, early life stages of freshwater mussels (glochidia) are parasitic and require a host fish to complete their development. Consequently, we also assess the potential effects of methomyl on host fish in the effects analyses for mussels. Similarly, effects to a listed species from impacts to their food items (such as aquatic invertebrates or prey fish) were included in our analyses. Our approach to applying the acute mortality data (LC_{50} values) for assessing lethal effects to listed species relies on the SSDs developed in the BE (Appendix 2-5 of the BE), when available. The HC_{05} (from the SSD) and its corresponding slope is generally used to assess mortality for each taxonomic group. When an SSD was not available, we used the lowest (most sensitive) LC_{50}. Unlike the acute mortality data, sublethal effects endpoints were largely reported as NOAECs and LOAECs for a variety of measurement endpoints and species within each effect category (i.e., growth, reproduction, behavior, sensory function). Consequently, EPA organized these data as effects arrays in the BE. Depending on the taxonomic group, we used these arrays to assess the likelihood or risk of species experiencing sublethal effects as a result of exposure to methomyl.

Effects to Fish and Aquatic-Phase Amphibians

We rely on toxicity data carried forward from the BE for our effects analysis to fish and aquatic phase amphibians. Overall, there was sufficient data on acute lethality to fish to create an SSD and there are several studies that address effects on growth. There were only two studies on reproduction and only three studies from the BE that tested effects on acetylcholinesterase activity. For aquatic-phase amphibians, there was only one study relevant for mortality and sublethal (growth) endpoints, each, and few species tested. In cases where no data were available, we used fish data as a surrogate for aquatic-phase amphibians.

We generally use the fish toxicity endpoints as surrogates for aquatic and aquatic-phase amphibians where there are few data for amphibians and discuss both taxa groups together in this section. The toxicity data used to assess the effects of methomyl are provided below and in Table 17. Incident reports are discussed at the end of this section. All data referenced in the following sections are from the Effects Characterization (Chapter 2) of the BE.

Mortality

In Appendix 2-3 of their BE, EPA provides a list of studies that they evaluated when selecting the most sensitive endpoints for their ESA risk assessment for fish (Table 17). Atheriniformes (Ictaluridae and Centrarchidae families), in general, appear to be the most sensitive to methomyl with LC_{50} values ranging from 300-2800 µg/L.

Acute toxicity estimates (96-hour LC_{50}) for methomyl range from 300 (MRID 40098001) - 32,000 µg/L (MRID 40098001) and span two orders of magnitude, indicating a wide range of sensitivity to methomyl among fish. The lowest definitive LC_{50} for methomyl is for a formulation (24% a.i.) tested on the channel catfish, *Ictalurus punctatus* (LC_{50} = 300 µg/L; (Mayer and Ellersieck 1986); MRID 40098001). The most sensitive species, channel catfish, is represented by a TGAI study used in the all-aquatic vertebrate SSD used to derive the HC_{05} value, so it should be noted that all species represented by 96-hour studies are also represented by this 96-hour TGAI study that has been incorporated in the all-aquatic vertebrate SSD.

For aquatic-phase amphibians, acute mortality (96 h LC_{50}) data for methomyl are available for three species from one study. The values range from 15,400-1,100,000 µg/L and span two orders of magnitude. The lowest LC_{50} value of 15,400 µg/L is for the marbled pygmy frog (*Microhyla pulchra*) (Lau, Karraker and Leung 2015); E171543) at 25°C. In this study, three amphibian species (also including the Asian common toad, *Polypedates melanosticutus*, and the brown tree frog, *Polypedates megacephalus*) were tested at temperatures ranging from 15-35ºC to analyze patterns in the temperature-dependence enhancement of methomyl toxicity. We did not use the data from this study in our final analysis for aquatic phase amphibians because there is not enough data to assess effects to amphibians and the HC_{05} value does take into account aquatic phase amphibian endpoints as it covers all aquatic vertebrate response data.

Sublethal effects

Growth

The lowest values for growth-related endpoints for fish are for the fathead minnow, with a NOAEC/LOAEC of 73/145 µg/L and an MATC of 103 (Howard, Rhodes and Mihalik 1991); MRID 46015305) based on significant inhibitions ($p<0.05$) of 9% reduction in length and 19% reduction in wet weight in the 145 µg/L treatment (see BE Table 2-7). Another two studies support effects in this treatment range, with significant reduction in length of the F1 generation at 142 µg/L (NOAEC/LOAEC for fathead minnow of 76/142 µg/L; (Strawn, Rhodes and Leak 1993); MRID 43072101), and survival at 117 µg/L (NOAEC/LOAEC for fathead minnow of 57/142 µg/L; (Driscoll and Muska 1982); MRID 131255/00118511).

There is one study representing one order and one species for aquatic-phase amphibians. The growth endpoints in the dataset range from 51.9 to 186 µg/L (see BE Figure 2-5). The lowest value was a NOAEC/LOAEC of 51.9/186 µg/L and an MATC of 99 for 5% reduction in hind-limb length and 7% reduction in snout-vent length in the African clawed from (*Xenopus laevis*) in the submitted amphibian metamorphosis assay (Fort, et al. 1977); MRID 48701402). In this study, the other sublethal effects measured (deformation, metamorphosis, thyroid histopathology, and wet weight) did not have measurable effects at the highest concentration tested (186 µg/L). Because there is only this study available to measure toxicity to amphibians, we use the fish data discussed above to address effects to growth on aquatic phase amphibians as we believe it better captures the breadth of sensitivities across these species.

Reproduction

The reproductive effects of methomyl on fish identified from registrant-submitted and open-literature studies range from 94.7-312 µg/L. The lowest value on the effects of methomyl on reproductive endpoints in fish is from a 21-day registrant submitted short term reproduction assay with the fathead minnow (*P. promelas*) (Hicks 2012); MRID 48701401). Fecundity (eggs per surviving female per reproductive day) and fertilization success were significantly reduced (23.3 and 1.6%, respectively) at 312 µg/L (NOAEC/LOAEC of 94.7/312 µg/L). The only other available study had a NOAEC/LOAEC for F1 hatching success in the same concentration range (142/280 µg/L); hatching success was significantly ($p \leq 0.05$) reduced (8.5%) in the 280 µg/L treatment (MRID 43072101). Significant effects were also seen in length and wet weight at this treatment level (and in length at 142 µg/L), as mentioned in the growth section above. However, no significant effects were seen in time to first spawn, F0 hatching success, mean eggs per spawn, mean spawning days or spawns per pair at the highest test concentration (280 µg/L).

There are no studies on reproduction for aquatic-phase amphibians thus the fish data are used as a surrogate.

Table 17. Toxicity values for methomyl for fish and aquatic-phase amphibians (Table 2-7 from the BE).

Taxa	Threshold Type	Effect (endpoint)	Value (µg a.i./L)	Duration of exposure/Species	Source
Freshwater Fish	Mortality	HC_{05}	335	4 days	5th percentile LC_{50} from all vertebrate SSD[1] (slope: 4.2, from Channel catfish; MRID 40098001/E6797)
	Sublethal	NOAEC for reduced growth ↓ length and wet weight (9% and 19% reduction at next higher concentration).	73/145 (NOAEC/ LOAEC) 103 (MATC)	35 days Fathead minnow (*Pimephales promelas*)	MRID 46015305 (Howard, Rhodes and Mihalik 1991)
Estuarine Marine Fish	Mortality	HC_{05}	335	4 days	5th percentile LC_{50} from all vertebrate SSD[2] (slope: 4.2, from Channel catfish; MRID 40098001/E6797)
	Sublethal	NOAEC for reduced growth ↓ length (12.9% reduction at next higher concentration)	260/490 (NOAEC/ LOAEC)	36 days Sheepshead minnow (*C. variegatus*)	MRID 45013202 (Boeri and Ward 1989)

			357 (MATC)		
Amphibians	Mortality	HC_{05}	335	4 days	5th percentile LC_{50} from all vertebrate SSD[3] (slope: 4.2, from Channel catfish; MRID 40098001/E6797)
	Sublethal	NOAEC for reduced growth ↓ length (5% reduction in hind-limb length and 7% reduction in snout-vent length at next higher concentration).	51.9/186 (NOAEC/ LOAEC) 99 (MATC)	21-day African Clawed frog (*Xenopus laevis*)	MRID 48701402 (Fort, et al. 1977)

Effects to Dietary Items

Additionally, we consider impacts to fish and aquatic-phase amphibian dietary items as part of our effects analysis. These include effects to fish, aquatic invertebrates, aquatic vegetation, phytoplankton, and zooplankton. Methomyl is known to affect growth and yield in both vascular and non-vascular aquatic plants. See the *General Effects to Plants* section below for a more detailed description of anticipated effects to aquatic plants.

Incident Reports

There are two aquatic animal incident reports in EPA's Incident Data System with a certainty index of 'possible,' 'probable,' or 'highly probable' (see Table 18 and BE Table 2-9).

The dates of the fish-kill incident reports range from 1992 to 2001 and both are fairly large (from approximately 125 dead fish to "several thousand"). The incidents involve a variety of fish species (bluegill, bowfin, carp, catfish, and threadfin shad) and in one, methomyl residues of 5.08 ppm were reported in composited gill samples. One of the incidents is associated with corn use, but for the other, the use site is not reported or unknown. The methomyl product involved is Lannate LV for one incident but not reported for the other incident; both incidents involve at least one pesticide in addition to methomyl. Overall, the available incident data indicate that exposure levels are sufficient to result in field-observable effects.

Table 18. Incident reports for fish involving methomyl (Table 2-9 from the BE).

INCIDENT NUMBER	YEAR	CHEMICAL(S) INVOLVED (PC CODE)	CERTAINTY INDEX (for methomyl)	STATE	LEGALITY (for methomyl)	USE SITE	SPECIES AFFECTED	DISTANCE	EFFECT/ MAGNITUDE	PRODUCT
I000108-001	1992	Methomyl (090301) Chlorpyrifos (059101)	Probable	GA	Undetermined	Corn - 200 acre field	Bluegill (*Lepomis macrochirus*), bowfin (*Amia calva*), and carp (*Cyprinus carpio*)	Measured concentrations of methomyl were taken from a pond and pond-overflow area receiving runoff from corn field. Distance given was 85-185 feet (assume this meant distance from edge of field).	125 fish killed	During a rainy two-week period prior to the fish kill, the corn plot had been treated with 5 applications of methomyl (aerial, 1.5 pints/acre), 4 applications of chlorpyrifos, 4 applications of fertilizer, and 2 applications of borax. The suspected cause of the fish kill was methomyl, as Lannate$^{\circledR}$ LV.
I013436-001	2001	Ammonia (005302)	Possible	CA	Undetermined	Unknown (the fish fill was in the San Joaquin River near the town of Lathrop)	29 fish species from 9 families including threadfin shad (*Dorosoma petenense*) and catfish (*Ictalurus* sp.)	Pesticide use in the watershed adjacent to the incident site in the San Joaquin River was not determined; evidence of pesticides use was from fish gill tissue samples.	Several thousand fish killed	Not reported. upon further review of the incident, it was acknowledged by California Fish and Game that un-ionized ammonia was the primary cause of the fish kill. Analyses of composited gill samples found the presence of several pesticides (dioxathion = 121.1 ppm; carbaryl = 1.75 ppm; carbofuran = 4.51 ppm; fenurin = 0.78 ppm; methomyl = 5.08 ppm; monuron = 5.83 ppm). However, these pesticides were not detected in the water samples.

Effects to Aquatic Invertebrates

The effects of methomyl on aquatic invertebrate species have been studied extensively and have been well-documented in the literature including studies on both freshwater and estuarine/marine invertebrates. Registrant-submitted studies involving aquatic invertebrates were also considered in EPA's BE to assess effects to this grouping of species, including acute and chronic laboratory studies with either technical or formulated methomyl (Table 19). As designated in the BE, the aquatic invertebrates taxonomic group includes species that occur in aquatic habitats during all or a portion of their life cycle, including certain insects (such as dragonflies, damselflies, stoneflies, aquatic beetles, etc.), aquatic or semi-aquatic snails and limpets, mussels and clams, and aquatic crustaceans, such as crayfish, isopods, and amphipods.

We made certain assumptions on the known effects of methomyl to the wide array of aquatic invertebrates we analyzed. Similar to the approach for other taxa where an SSD could be described, a single dose-response relationship, based on the HC_{05}, was used to describe mortality of all listed aquatic invertebrate species except mussels and snails. The reasons for using this approach include the range of the available data for the different aquatic invertebrate species and a wide range of within-Order variability across a number of studies. We evaluated snails and mussels using a different approach (described below) due to differences in sensitivity of mussels compared to other aquatic invertebrates.

The aquatic invertebrates mortality threshold is based on the HC_{05} value from the pooled freshwater and estuarine/marine SSD for the taxon. We did not pursue sub-lethal effects for the analysis at this time due to the response threshold values being of similar magnitude for both mortality and sub-lethal endpoints (see Table 19 in this Opinion or Table 2-11 from the BE). The relatively high estimated environmental concentration(s) (EEC)s aquatic invertebrates are likely to experience based on the waterbodies in which they are found (see Table 3-5 of the BE) will elicit mortality prior to any sub-lethal effects as well. Therefore, the mortality toxicity data used to assess the effects of methomyl are provided below, along with a discussion of the available incident reports for methomyl and aquatic invertebrates.

Table 19. Effects endpoints used to derive mortality and sublethal thresholds for determining effects to listed aquatic invertebrates (adapted from Table 2-11 from the BE).

Taxa	Threshold Type	Effect (endpoint)	Value (µg a.i./L)	Duration of Exposure	Source
Freshwater Invertebrates	Mortality	HC_{05}	3.94	48 or 96 hours	5th percentile LC_{50} from pooled invertebrate SSD (slope = 4.5)
Freshwater Invertebrates	Sublethal	Reproduction ↓ 29.5% reduction in young/female	1.6/3.5 (NOAEC/LOAEC) 2.4 (MATC)	21 days (*D. magna*)	MRID 1312541 (Britelli and Muska 1982)
Estuarine/Marine Invertebrates	Mortality (non-mollusk)	HC_{05}	3.94	48 or 96 hours	
Estuarine/Marine Invertebrates	Sublethal (non-mollusk)	Reproduction ↓ 57.4% reduction in progeny counts/female	29.1/59.1 (NOAEC/LOAEC) 41.5 (MATC)	28 days (*A. bahia*)	MRID 45013203 (Ward, Magazu and Boeri 1999)

Mortality

Aquatic Insects and Crustaceans:

Mortality data were available (submitted by registrants or available in ECOTOX database) for several different orders of aquatic invertebrates.

Acute mortality data (48- and 96-hour EC_{50}/LC_{50}s) reveal a large range in sensitivity with three orders of magnitude difference in the values from 2.11 µg/L for the water flea (*C. reticulata*; (Mano, Sakamoto and Tanaka 2010): E154905) to 8,930 µg/L for the northern house mosquito (*C. pipiens*). The reported EC_{50}/LC_{50} values are from studies with either a 48 or 96-hour duration which is the standard for acute aquatic invertebrate toxicity tests. From these tests, EPA was able to form the basis of the SSD and pooled the data from both estuarine/marine and freshwater taxa. The toxicity value from the BE to describe mortality as an endpoint for all aquatic invertebrates, also used for the Opinion, was the pooled aquatic invertebrate HC_{05} LC_{50} of 3.94 µg/L; slope of 4.5. Thus, we used this value for both aquatic insects and crustaceans.

Mollusks (mussels and aquatic snails):

No acute mortality (LC_{50}) data for methomyl are available for mollusks; instead, we reviewed other carbamate data for mollusks to address toxicity for methomyl. We reviewed data for carbaryl, oxamyl, and aldicarb. Data are shown below in Table 20.

From the registration review of aldicarb, Eastern oysters (*Crassostrea virginica*) are approximately 3 orders of magnitude less sensitive than mysid shrimp to aldicarb (8,800 ppb vs. 12 ppb) and generally 2-3 orders of magnitude less sensitive than freshwater (non-mollusk) aquatic invertebrates (8,800 ppb vs. 10-5,000 ppb; Table 21).

Data for carbaryl from the 2021 BE (US EPA 2021a) (Table 20), indicated that the HC_{05} from the SSD for mortality for mollusks is 6,600 ppb based on toxicity data from among five orders and 15 species. The SSD pooled data from both estuarine/marine and freshwater species. This value is within the same order of magnitude to that observed for the toxicity endpoint for the Eastern oyster (*C. virginica*) and aldicarb described above. The HC_{05} for all non-mollusk aquatic invertebrates for carbaryl is 1.6 ppb. Thus, the sensitivity for mollusks, being three orders less sensitive than all other aquatic invertebrates for carbaryl, is also within the same sensitivity comparison for mollusks compared to most other aquatic invertebrates as is described for aldicarb above.

Based on data provided by EPA from the registration review of oxamyl, Eastern oysters (*C. virginica*) are about four orders of magnitude less sensitive than mysid shrimp and two orders of magnitude less sensitive than daphnids when exposed to technical oxamyl (28 ppm vs. approximately 0.05 – 0.5 ppm; see Table 22 below and US EPA 2017b).

Table 20. Carbamate data to describe effects to mollusks and as compared to non-mollusk aquatic invertebrates.

Species	Aldicarb EC/LC$_{50}$ (ppm)	Carbaryl EC/LC$_{50}$ (ppm)	Oxamyl EC/LC$_{50}$ (ppm)
mollusk	Eastern oyster = 8.8	Mollusk SSD HC$_{05}$ = 6.6	Eastern oyster = 28
Non-mollusk aquatic invertebrate	pink shrimp = 0.012	Non-mollusk aquatic invertebrate HC$_{05}$ = 0.0016	Daphnia = 0.05-0.5

Table 21. Aldicarb data to describe the range of toxicity to different aquatic invertebrate species from other carbamates (adapted from the registration reviews of Aldicarb (US EPA 2015).

Species	96-hour or 48-hour EC$_{50}$/LC$_{50}$	Citation
Water flea, *Daphnia magna*	48-h EC$_{50}$ = 410 ppb	MRID 107395 (Vilkas 1977)
Water flea, *Daphnia magna*	48-hr LC$_{50}$ = 75 ppb	(Song, Stark and Brown 1997)
Mosquito, *Aedes aegypti*	48-hr LC$_{50}$ = 290 ppb	Song *et al.*, 1997
Brine shrimp, *Artemia sp.*	48-hr LC$_{50}$ = 5460 ppb	Song *et al.*, 1997
Mosquito, *Aedes taeniorhynchus*	48-hr LC$_{50}$ = 150 ppb	Song *et al.*, 1997
Water flea, *Daphnia magna*	48-hr EC$_{50}$ = 583 ppb	(Moore, et al. 1998)
Amphipod, *Hyalella azteca*	48-hour EC$_{50}$ = 3990 ppb	Moore *et al.*, 1998
Midge, *Chironomus tentans*	48-hour EC$_{50}$ = 20 ppb	Moore *et al.*, 1998

Species	96-hour or 48-hour EC_{50}/LC_{50}	Citation
Water flea, *Daphnia laevis* (juvenile)	48 hr EC_{50} =65 ppb	(Foran, Germuska and Delfino 1985)
Water flea, *Daphnia laevis* (adult)	48 hr EC_{50} = 51 ppb	Foran *et al.* 1985
Aldicarb sulfoxide	***Aldicarb sulfoxide***	***Aldicarb sulfoxide***
Water flea, *Daphnia magna*	48-h EC_{50} = 696 ppb	MRID 45592114
Water flea, *Daphnia laevis* (adult)	48 hr EC_{50} = 43 ppb	Foran *et al.,* 1985
Water flea, *Daphnia laevis* (juvenile)	48 hr EC_{50} =57 ppb	Foran *et al.,* 1985
Aldicarb sulfone	***Aldicarb sulfone***	***Aldicarb sulfone***
Water flea, *Daphnia magna*	48-h EC_{50} = 280 ppb	Acc# 096727 (Anonymous 1976)
Water flea, *Daphnia laevis* (adult)	48-h EC_{50} =369 ppb	Foran *et al.,* (1985)
Water flea, *Daphnia laevis* (juvenile)	48-h EC_{50} =556 ppb	Foran *et al.,* (1985)
Qualitative Studies		
Midge, *Chironomus riparius*	Symptoms of intoxication	(Kallander, Fisher and Lydy 1997)
Midge, *Chironomus riparius*	24-hr LC_{50} (water only) = 9.9 ppb 24-hr LC_{50} (spiked water) = 10.0 ppb, 24-hr LC_{50} (spiked sediment) = 26.7 ppb	(Lydy, et al. 1990)
Scud, *Gammarus italicus* Goedm.	96-hr LC_{50} = 420 ppb	(Pantani, et al. 1997)

Table 22. Oxamyl data to describe the range of toxicity to different aquatic invertebrate species from other carbamates (adapted from the registration reviews of oxamyl (US EPA 2017b)).

Species	96-hour or 48-hour EC_{50}/LC_{50}	Citation (MRID or ECOTOX)
Acceptable Studies	**Acceptable Studies**	**Acceptable Studies**
Mysid shrimp, *Americamysis bahia*	0.0465	48878501
Eastern oyster, *Crassostrea virginica*	0.1	113414
Water flea, *Daphnia magna*	0.319	44984501
Water flea, *Daphnia magna*	0.49	157954
Grass shrimp*, Palaemonetes pugio*	0.7	113412
Eastern oyster, *Crassostrea virginica*	28	49020501
Supplemental Studies	**Supplemental Studies**	**Supplemental Studies**
Midge, *Chironomus pulmosus*	0.17	40098001
Midge, *Chironomus pulmosus*	0.18	40098001
Water flea, *Daphnia magna*	0.47	40098001
Fiddler crab, *Uca pugilator*	5.5	113413
Water flea, *Daphnia magna*	5.6	40098001

Species	96-hour or 48-hour EC_{50}/LC_{50}	Citation (MRID or ECOTOX)
Qualitative Studies	**Qualitative Studies**	**Qualitative Studies**
Scud, *Gammarus italicus*	0.22	ECOTOX 18621
Scud, *Echinogammarus tibaldii*	0.30	ECOTOX 18621

Mussels (Unionidae and Margaritiferidae)

Due to the sensitivity differences among mussels as compared to other aquatic invertebrate species, the effects to mussels were assessed separately from the rest of the aquatic invertebrates. We used the related carbamate data as described above to assess direct effects to listed mussels using the carbaryl mollusk HC_{05} of 6.6 ppm as the analysis showed there were no differences among the estuarine/marine and freshwater mollusks in their response to exposure to carbaryl and there was a similar response among mollusks to aldicarb and oxamyl (see Table 20 and Table 21 above).

There are approximately100 listed species of freshwater mussels that are considered in this consultation that generally belong to two families, Unionidae and Margaritiferidae, of which several species included in the SSD analyses were members.

For effects to mussel species via their host fish, which are needed to complete the mussel species' life cycles, we used the HC_{05} LC_{50} for fish toxicity (300 µg/L).

Aquatic Snails (Assimineidae, Hydrobiidae, Lymnaeidae, Physidae, Planorbidae, Pleuroceridae, Viviparidae):

There are no specific methomyl data for aquatic snails. Instead, we looked to other carbamate acute toxicity data for freshwater snails. Several of the species used in the SSD developed for carbaryl for mollusks were freshwater snails from multiple studies such as *Biomphalaria glabrata*, *Bellamya bengalensis*, *Pomacea patula,* and *Pila globose*.

Due to the lower sensitivity to related carbamates other than methomyl that snails potentially exhibit compared to other aquatic invertebrates, aquatic snails (with mussels) were considered separately from other aquatic invertebrates in our analyses. We used the related carbamate data as described above to assess direct effects to listed aquatic snails from methomyl using the carbaryl mollusk HC_{05} of 6.6 ppm.

There are 35 species of freshwater snails from the mainland United States considered in this consultation. Freshwater snails live in permanent freshwater sources of varying sizes and characteristics and do not tolerate drought conditions nor brackish or marine conditions. In general, endangered and threatened freshwater snails live in springs or flowing waters such as streams and rivers, however, individuals may survive in lentic conditions where the waterbodies maintain adequate food and water quality resources.

Freshwater snails are generally divided into two subclasses Prosobranchia and Pulmonata (Dillon 2000). Prosobranchs share a few characteristics: breath through gills, have an operculum, and reproductive strategies include separate sexes with occasional parthenogenesis (i.e., reproduction without fertilization or cloning), and rare hermaphroditism (the state an organism having both male and female sex organs or other sexual characteristics, either abnormally or (in the case of some organisms) as the natural condition). Pulmonates do not have gills, use the mantle surface for respiration, and may carry a surface-derived, air bubble in their mantle cavity; do not have an operculum; and are hermaphrodites.

Freshwater snails use their radula to scrape algae and organic debris from firm substrates like rocks, woody debris, root mats, and submerged plants. However, some can feed on algae and organic debris imbedded within fine sediments, collecting the food in a fine mucus stream that flows directly into the mouth. Another mode of feeding can occur in rivers with large volumes of suspended organic matter. The snail may lie on their side, turning their foot up into the water column to collect food which is then moved by a mucus stream into the mouth. Because all freshwater snails feed on algae and organic debris, we do not expect differences in exposure rates due to food resources or the method used to feed.

Incident Reports for Aquatic Invertebrates

As of January 22, 2020, there are two aquatic animal incident reports in EPA's Incident Data System with a certainty index of 'possible,' 'probable,' or 'highly probable' (see Table 2-9 and Attachment 2-2 in the BE, for details). None of the reported incidents involved aquatic invertebrates (although one incident in EPA's Incident Data System aggregate database was classified as "other non-target" and could have involved aquatic invertebrates); however, absence of reported incidents does not ensure that none occurred. Overall, the available incident data indicate that exposure pathways for methomyl are complete (can be traced from the source to the organism impacted) and that exposure levels are sufficient to result in field-observable effects to aquatic organisms, in general.

General Effects to Plants

Methomyl exposure to plants occurs through contact exposure, either from direct spray or dissolved in runoff. Toxicity data provided by the EPA (USEPA 2021) are primarily from greenhouse experiments or fields studies using planted crops, which are conducted under conditions that mimic those occurring on agricultural fields. These studies use spray application designed to expose plants to predetermined concentrations of active ingredients and are carried out for a set duration (e.g., 21 days) with a desired endpoint in mind (e.g., plant height, plant weight, seedling emergence, or survival).

Effects to Aquatic Plants

The most sensitive toxicological data available regarding methomyl's effects to aquatic plants is summarized below in Table 23, which comes from registrant submitted studies cited in EPA's

BE (USEPA 2021). In one study, researchers observed up to 13% reductions in dry weight of the freshwater blue-green algae *Tolypothrix tenuis* exposed to 100 mg/L methomyl for seven days. Additionally, researchers observed increased glucose and phosphorus uptake and decreased carotene production, indicating that biochemical effects also occurred with exposure. Another study found up to 50% reduced population abundance in the freshwater green algae *Pseudokirchneriella subcapitata* exposed to 60 mg/L methomyl at three days post-exposure.

A registrant-submitted study that exposed *P. subcapitata* to a formulation of methomyl (Lannate 90 SP) for 96-hours observed adverse effects to growth. The LOAEC was 7.24 mg a.i./L, which had a 9% reduction in both yield and cell density, as well as a 2% reduction in mean growth. This study calculated a NOAEC of 3.69 mg a.i./L and a 50% effect level (IC$_{50}$) of 43.1 mg a.i./L.

Similarly, a registrant-submitted study that exposed duckweed (*Lemna gibba*) to formulated methomyl (Lannate 90 SP) observed reduced frond number and growth rate with increasing methomyl concentrations. The observed NOAEC was 29.8 mg a.i./L and LOAEC was 59.5 mg a.i./L, which caused a 19% reduction in frond yield and 7% reduction in growth rate as compared to controls. The researchers also observed reduced total biomass and biomass growth rate at higher concentrations of methomyl. The researchers determined that the 50% growth effect level (IC$_{50}$) was 182 mg a.i./L.

Table 23. Summary of aquatic plant toxicity data.

Taxa		Effect	Concentration (mg a.i./L)	Endpoint
Non-vascular plants		Sublethal - growth	3.69	NOAEC
			7.24	LOAEC
			43.1	IC$_{50}$
Vascular plants		Sublethal – growth	29.8	NOAEC
			59.5	LOAEC
			182	IC$_{50}$

Effects to Terrestrial Plants

The available toxicology data regarding methomyl's effects to terrestrial plants is summarized below in Table 24, which comes from a registrant submitted study cited in EPA's BE (USEPA 2021). The study exposed ten different crop species to formulated methomyl for 21 days, tracking survival, plant height, and plant weight. The tested species included: corn (*Zea mays*), onion (*Allium cepa*), ryegrass (*Lolium perenne*), oat (*Avena sativa*), cucumber (*Cucumis sativus*), pea (*Pisum sativum*), soybean (*Glycine max*), tomato (*Lycopersicon esculentum*), oilseed rape (*Brassica napus*), and sugar beet (*Beta vulgaris*). These test species cover seven orders of plants, including two monocots (i.e., Poales and Asparagalles) and five dicots (i.e., Cucurbitales, Fabales, Solenales, Brassicales, and Caryophyllales). The researchers found no differences in the percent of seedling emergence between treated and control plants, even at the highest concentrations tested (up to 3.01 lbs a.i./acre). Similarly, the researchers did not observe any effects to survival, plant height, or plant weight at the end of the study. Given that no effects were observed, we use the highest test concentration reported to represent the NOAEC and assume the LOEAC and the 25% effect level (i.e., IC_{25}) occur at some concentration above this level.

Table 24. Summary of terrestrial plant toxicity data.

Taxa	Effect	Concentration	Endpoint
Monocot	Mortality	2.97 lbs a.i./acre	NOAEC
	Sublethal – growth	>2.97 lbs a.i./acre	IC_{25}
Dicot	Mortality	2.97 lbs a.i./acre	NOAEC
	Sublethal – growth	>2.97 lbs a.i./acre	IC_{25}

Incident Reports

As of the release of the EPA's final biological evaluation, there were no pesticide incident reports submitted to the EPA involving aquatic plants. There were three incident reports involving terrestrial plants with a certainty index of 'possible' or 'highly probable.' One of these incidents was a result of misuse, while the legality of the other incidents was undetermined. All three incidents are from 2010 and involved minor damage to crops (e.g., light speckling on leaves) treated with formulated methomyl products.

Exposure

Methomyl enters the environment via direct application to use sites and may be sprayed directly onto soil, foliage, or impervious surfaces. Spray drift and runoff are primary routes of offsite transport. Rainfall transports methomyl off-field through runoff, soil erosion, and leaching. These mechanisms may transport methomyl to surface water. Based on methomyl's aerobic soil metabolism and aerobic and anaerobic aquatic metabolism data, methomyl is not considered persistent[13] in the environment, with half-lives on the order of days to weeks (representative[14] half-life values range from 2.5 to 52 days). Under anaerobic conditions methomyl degradation is likely to be faster than under aerobic conditions (Smelt, et al. 1983) particularly in the presence of reduced iron (Bromilow, et al. 1986). It is stable to hydrolysis at lower pHs (neutral to acidic),

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[13] Based on the Toxic Release Inventory classification system where half-lives greater than 60 days in water, soil, and sediment are considered persistent and half-life greater than 6 months are considered very persistent (USEPA, 2012a).

[14] Half-live values were recalculated using the NAFTA guidance in estimating degradation kinetics (NAFTA 2012).

but it degrades slowly in alkaline conditions (DT_{50} = 36-266 days). Hydrolysis half-lives indicate that methomyl is classified as persistent in aquatic and terrestrial environments where microbial activity is not present; however, microbial activity is expected in most natural environments.

Methomyl is classified as mobile (K_{FOC}s range from 32-61 L/kg)[15] and has the potential to reach surface water through runoff and soil erosion. Overall, soil/sediment-water distribution coefficients increase with increasing percent of organic-carbon. Methomyl has the potential to reach groundwater especially in high-permeability soils with low organic-carbon content and/or the presence of shallow groundwater. The maximum depth of leaching in the terrestrial field dissipation studies is 30 inches. Predominantly methomyl will be present in the water column and to a lesser extent as bound to sediments. Based on measured octanol-water partition coefficients (K_{ow}s) and K_{FOC}s, exposure to sediment-dwelling organisms is likely to occur in lesser extent as compares to organisms in water column. Low octanol/water partition coefficient also suggests that the chemical will have a low tendency to accumulate in aquatic and terrestrial organisms (BE Table 3-1).Major methomyl degradates include methomyl oxime (S-methyl-N-hydroxythioacetimidate), acetonitrile, acetamide, and CO_2. Methomyl oxime (S-methyl-N-hydroxythioacetimidate) was detected at a maximum of 44% in the alkaline hydrolysis study. None of the major methomyl degradates identified in the environmental fate studies is considered to be of toxicological concern based on the available data. None of these degradates contain a carbamate functional group. Furthermore, based on previous Quantitative Structure-Activity Relationship (QSAR) analyses, the degradates are estimated to be less toxic than the parent (see USEPA 2012c).

In general, EPA derived exposure estimates for listed species using fate and transport models. The methodology used to derive the geographically specific estimated environmental concentrations (EECs) are described and presented in Chapter 3 of EPA's BE. EPA used combinations of several transport models including the Pesticide Root Zone Model (PRZM5), the Variable Volume Water Model (VVWM), Terrestrial Residue Exposure (T-REX), and AgDrift (version 2.2.1) to estimate concentrations in aquatic and terrestrial habitats used by listed species, assuming pesticides were applied according to label specifications.

Rate, Frequency, and Number of Applications

Estimated environmental concentrations (EECs) are influenced, in part, by the allowable manner of pesticide use as described by the label, including the application rate, frequency of application, and the maximum number of applications per season or year. Generally, EPA modeled EECs using the highest allowable application rate and minimum re-entry interval for each labeled use. We recognize that methomyl will not always be used in a manner that produces maximum concentrations in the environment. Where we found these concentrations result in effects to listed species, we looked to usage data to determine whether it is reasonable to assume that methomyl is used in a manner to produce such concentrations.

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[15] Mobility was classified using the Food and Agriculture Organization (FAO) classification system (FAO, 2000) and supplemental sorption coefficients.

In selecting application dates for aquatic modeling, EPA considers several factors including label directions, timing of pest pressure, meteorological conditions, and pre-harvest restriction intervals. Agronomic information was consulted to determine the timing of crop emergence, pest pressure and seasons for different crops. General sources of information include crop profiles agricultural extension bulletins, and/or available state-specific use information.

Methomyl may be applied during different seasons, and the directions for use indicate the timing of application, such as, at planting, dormant season, or foliar (e.g., when foliage is on the plant), etc. For most methomyl uses, the PWC model inputs for the application dates were chosen based on these timings, the crop emergence and harvest timings specified in the PWC scenario, and precipitation data for the associated meteorological station. Application dates were selected to represent conservative and reasonable estimates. If applicable, dormant seasons were assumed to occur between November and February, the predominant period throughout the country when crops are dormant. Foliar applications were assumed to occur when the crop was on the field in the PWC scenario. Pre-harvest intervals (the minimum time between an application and harvest) were also considered. Applications would not occur closer to harvest than allowed by the pre-harvest interval.

Determining Percent of the Population That Could Be Exposed to Methomyl

Overlap with species range: We derive the estimate of exposure for each species, in part, by determining the extent that the range of a species overlaps with use site categories for which the pesticide is registered, combined with anticipated off-site transport. The process for establishing the use site footprint is generally described in Attachment 1-3 of EPA's BE. Briefly, methomyl use sites were binned (i.e., categorized) by the general land cover class that best represents the use pattern (e.g., grapes are categorized with other orchards while cole crops (e.g., cabbage, broccoli, Brussels sprouts, and kale) are binned with vegetables and ground fruit; see Table 25). EPA lists information on crop or use, application timing, application rates, method, and any geographic restriction in the Master Use Summary Table (Appendix 1-3 of the BE). To map use sites on the landscape, EPA used the 2014 National Agricultural Statistics Service (NASS) Census of Agriculture (CoA) crop acreage reports and the 2012 NASS CoA crop harvested data to confirm the presence or absence of individual use sites or crops within a county. Unless the label limits a use pattern to a particular geographic area, all regions are modeled where there are crop acres or harvested data. For those crops/use sites where NASS harvested data are unavailable, the crop or use site was assumed to occur within that county based on the information provided by the CDL representing the landcover groups. Limited data are available for crops grown in the Pacific Islands and Caribbean. For Hawaiʻi we use the Hawaiʻi state agricultural data layer that describes the distribution of specific crops throughout the state (Hawaii Statewide GIS Program).

Table 25. Composition of Use Data Layers (UDLs) for methomyl.

Use Data Layers for Methomyl
Citrus: Grapefruit, Lemon, Oranges, Tangelo, Tangerine
Corn: Field Corn, Sweet Corn, Pop Corn, Seed Corn

Use Data Layers for Methomyl
Cotton
Wheat: Durum Wheat, Winter Wheat, Spring Wheat
Vegetables and ground fruit: Anise (fennel), Asparagus, Beans (dry and succulent), Beets, Blueberries, Broccoli, Broccoli Raab, Brussels sprouts, Cabbage, Carrots, Cauliflower, Celery, Chicory, Chinese Broccoli, Chinese Cabbage, Collards, Cucumbers, Collards, Eggplant, Endive (Escarole), Garlic, Horseradish, Leafy Green Vegetables (beet tops, dandelion greens, kale, mustard greens, parsley, Swiss chard, and turnip greens), Lentils, Lettuce (head and leaf), Melons, Mint (peppermint and spearmint), Mustard, Onions (green and dry bulb), Peas, Peppers, Pomegranate, Potatoes, Tomatoes, Summer squash, Tomatillos
Other Orchards: Peaches, Apples, Pecans, Pears, Pomegranates, Nectarines, Avocados, Non-bearing fruit, nut, grape
Other grains: Sorghum
Other row crops: Sunflower, Peanuts, Tobacco, Sugarbeets
Pasture: Alfalfa
Bermuda Grass
Soybean
Turf/Sod Grass

The “percent overlap” for each use site is generally divided between on-field overlap, off-field overlap, and total overlap. On-field overlap refers solely to the footprint of the use site itself. Off-field overlap is comprised of the 90-m offsite transport area outside of use sites. The total overlap combines these two metrics. When mapping use sites, EPA found redundancies among various use sites. That is, mapped use sites are not mutually exclusive of one another. For instance, there may be landcover that is part of both the “vegetables and ground fruit” category and the “other grains” category. For this reason, combining the percent overlap for use sites may overestimate the total amount of a species’ range that is overlapping with use sites.

To further identify methomyl use areas, we made the following refinements and deviations from the methods described in EPA’s BE:

- Based on discussions with methomyl's primary registrant, TKI[16], we concluded, that for landcovers among the pasture category as defined in the BE, methomyl is consistently used for pest control on alfalfa. Other uses of pasture were deemed to be extremely limited and unlikely to cause effects to listed species. To determine effects to listed species, we mapped this category with only the alfalfa layer of the CDL.

Distribution of individuals within the range:

We determined the exposure of species to pesticides at a population level by considering the overlap of pesticide use sites and associated off-site transport with individuals within the landscape, as determined by the range of the species and the anticipated distribution of individuals within the range. We estimate the distribution of individuals by several types of factors, including: habitat preference, life history traits, behaviors such as colonial nesting or flocking, type of water body (flowing or static), size of water body (for aquatic or semi-aquatic species), and known areas of high or low density of individuals of the species. Distribution can also include areas where species may congregate to breed or roost on a short-term basis, such as leks or spawning sites. Areas of high densities of individuals can increase the vulnerability of a species if they overlap with pesticide use sites. However, specific information regarding the distribution of species varies. Where information is readily available for individual species or taxonomic groups, it is incorporated into the analysis in a qualitative manner. For species where no information is available, we will assume that species are uniformly distributed throughout the range. However, we may consider that species may be more or less likely to be in use areas based on the suitability of habitat and availability of resources. The assumption of a uniform distribution can either increase potential exposure by artificially expanding the area of exposure to the whole range, or decrease the potential exposure by failing to identify high density areas that overlap with pesticide use sites.

Seasonal exposure:

Species may avoid exposure to a pesticide due to life history factors such as migration, estivation, or hibernation. Where species may avoid exposure to a pesticide for a particular life stage or life event, it was considered in the analysis. For example, whooping cranes in the Aransas-Wood Buffalo National Park population do not breed in the action area (they only winter and migrate within the action area) and, therefore, we do not anticipate effects to breeding from the action under consideration. When species may not be present during pesticide applications, we considered whether residues were likely to remain in the environment when the species returns to the site. As our analysis generally evaluated the effect of a single exposure per year, we did not modify the anticipated risk based on the percent of the time spent in the action area, as each species could be exposed at least once per year regardless of that factor.

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[16] This information is considered Confidential Business Information (CBI) by TKI, and thus is discussed only at a coarse level in this Opinion and summarized in combination with other information.

Volatilization and Atmospheric Drift

Based on a relatively low Henry's Law Constant (2.1 x 10^{-11} atm-m^3/mol) and moderate soil/water partitioning, methomyl has low volatilization potential from soil.

Air monitoring data collected from the 1960s through the 1980s as summarized by (Majewski and Capel 1995), do not indicate the presence of methomyl in the atmosphere. The authors' review a single study which tested for methomyl in ambient air at three residential sites near an agricultural area in Salinas, California which were sampled during a high pesticide use month. Methomyl was not detected at any of the air monitoring sites (the level of detection was 35 nanograms per cubic meter).

The January 2008 report by the Western Contaminants Assessment Project (WACAP) yielded no detections of methomyl in the atmosphere or evidence of long-range transport. A copy of the report can be found **here**. A report generated by (Daly, et al. 2007) did not sample for methomyl which is expected since long range transport and volatilization of methomyl are not expected to be major pathways of concern.

Terrestrial-specific Exposure Factors

Terrestrial organisms can be exposed to pesticides in the environment through diet, direct spray, preening, drinking water, and inhalation at different life stages. Various factors influence the likelihood and extent of this exposure at both the individual and population level including both properties of the pesticide (e.g., number of applications, persistence) and life history factors of the species (e.g., dietary preference, feeding habits, species distribution, and local and long-distance movement).

Routes of Exposure

Ingestion - dietary exposure

A primary route of exposure to pesticides for terrestrial organisms is from ingestion, either by feeding on food items that have been contaminated after a pesticide application or through direct consumption of the pesticide (e.g., in the granular or bait form). For contaminated food items, exposure may be to pesticide residues that have either been biologically incorporated into plant or animals or deposited on the surface or the plant or animal. Secondary predators may also be exposed to pesticide within prey that has not yet been biologically incorporated but resides within the gastrointestinal tract of prey (Hill and Mendenhall 1980).

The frequency of food ingestion can vary by species. Some species may hunt or graze on dietary items daily, either at certain times (e.g., dawn and dusk), or throughout the day. Other species, such as predators and scavengers (e.g., California condor, snakes) may ingest a prey item or carcass and not feed again for one or more days. Life stage may also affect the frequency of feeding, as young of altricial species may be reliant on parents to bring food back to the nest site one or more times per day. Long-distance migrators such as the red knot may gorge feed at stopover locations, then travel long distances on food stores from these events.

For terrestrial species, EPA's BE provides EECs based on output from the T-REX model on and in food items of terrestrial vertebrates as both concentration-based and dose-based values (as described in Attachment 1-7) for exposure on use sites and via spray drift. Pesticide concentrations vary by dietary item and use (i.e., incorporating use-specific application rates and frequency). Therefore, individual species may be associated with multiple EECs based on the number of food items consumed and the number of use sites that the species overlaps with.

For our analysis, listed terrestrial species have been documented to consume from 1 to 11 dietary items. For many species, dietary preferences are unknown, or the information is not readily available. For these species, we assume that individuals are equally likely to consume any of the dietary items identified. Some species may have known dietary preferences. In these cases, we have increased confidence in the likelihood of exposure to the pesticide concentration associated with preferred dietary items. However, even if a dietary item is less preferred, it should be considered whether it may be consumed at a high enough rate to cause effects even once over the course of the entire year. In some cases, prey exposed to pesticides could be taken preferentially, as such exposure may make it more susceptible to predation (e.g., (Hunt, et al. 1992)).

The breadth of EECs that are likely to be encountered by individuals may also be influenced by the degree of mobility of the species. The EECs derived from the T-REX model are based on empirical values of dietary items collected from fields following pesticide applications that vary both across and within application sites. As such, a range of potential EECs is generated based on these values and the designated application rate. The BE provides two EECs from this range, the mean and upper bound.

For each application of methomyl, T-REX produces a time series of concentrations on each dietary item, starting immediately after application and progressing daily. For our assessment, we have chosen to look at the peak EECs from this time series. For some dietary items, such as plants, peaks will occur immediately after an application and decrease through time. For other dietary items, such as small mammals and birds, peaks may not occur until days after an application as the prey item itself continues to be exposed to pesticide residues prior to it being preyed upon by the listed species under consideration. Peak values can also be influenced by multiple applications and the length of time between those applications. For mobile species, we acknowledge that looking at peak values may overestimate exposure, as individuals may not be present or may be foraging in a different location when peak values occur. However, mobile individuals may also have more opportunities for exposure to peak values if their foraging areas pass through multiple areas of pesticide use. For instance, wood storks typically forage 5 to 12 miles from nesting sites but have been documented foraging as far as 80 miles. Species such as this may be exposed to methomyl as a consequence of multiple application events (i.e., from different fields or use sites, or from multiple applications on the same field), or from feeding multiple days on the same use site where concentrations may remain high enough to result in adverse effects. Our analysis does not capture the risk to species that may be exposed repeatedly or on multiple occasions throughout the year; we assess the risk of effects to individuals following a single exposure event. In this manner, we are less conservative, but by using peak EECs we hope to capture the breadth of effects that may occur to species regardless of the way they are exposed. For species with little to no movement, individuals on or near use sites have a high likelihood of seeing peak EECs following an application, as well as subsequent EECs from the same application that may result in adverse effects. However, they may be unlikely to experience exposure from spray events from other use sites, and therefore, are less likely to have exposure from applications to different sites.

Peak EECs are used to assess mortality and sublethal effects from both acute and chronic exposure. As described above (Effects to Terrestrial Species), most toxicity studies that are designed to examine sublethal effects such as growth, behavior, and reproduction are chronic studies in which test subjects may be exposed to pesticides for long periods of time (e.g., 20-week reproduction studies for birds). Endpoints measured in these studies aggregate the combined effects of that exposure that may be a result of one or more responses (e.g., parental behavior of adults versus developmental effects to young that combined result in reducing hatching). It is not generally possible to ascertain the specific response, or timing of that response, that caused the ultimate effects. For reproduction in birds, for example, it is possible that short exposures at some point during the 20-week exposure cycle were ultimately responsible for effects. Without information to suggest that effects are only likely to result from longer exposures, we assess the potential for methomyl to affect individuals based on a single peak EEC value.

Contact exposure – direct spray or contact with contaminated media

Terrestrial species may be exposed to pesticides through direct contact with a pesticide followed by dermal absorption. Exposure may occur from pesticides directly deposited on an individual during a spray or individuals contacting contaminated media after a spray, such as walking on a treated field or brushing against treated foliage. Studies involving cholinesterase-inhibiting pesticides, particularly organophospahes, have shown this can be a significant route of pesticide exposure for terrestrial vertebrates, especially for birds (Henderson, Yamamoto, Fry, Seiber, & Wilson, 1994; Vyas , et al., 2006; Schafer, Brunton, Lockyer, & De Grazio, 1973; Hudson, Haegele, & Tucker, 1979). While data are lacking for contact toxicity of methomyl in other terrestrial vertebrates, acute studies in mammals described in the BE showed dermal exposure to be a much less sensitive route of exposure than oral toxicity, with no mortalities at concentrations that were orders of magnitude greater than the mammalian oral acute LD_{50}. As such, we base our analysis on dietary toxicity as the primary route of exposure and effects to terrestrial vertebrates. While we acknowledge dermal contact can be an additional route of exposure that may increase the overall body burden of terrestrial vertebrates, we do not anticipate this type of exposure will result in additional measurable impacts to individuals that are not already accounted for given the conservative nature of the dietary assessment (i.e., diets consisting of only forage/prey items exposed at maximum concentrations) and the comparative data between the two routes of exposure.

For terrestrial invertebrates, we estimate contact exposure to methomyl in the same manner as dietary exposure, but use the species being assessed in place of the dietary item. Specifically, the output from the T-REX model contains the concentration of pesticide on the surface of the terrestrial invertebrate and we use this value as the contact dose for the listed species.

Ingestion from preening or grooming

Birds and mammals exposed to pesticides on their feathers or fur through direct spray or contact with contaminated media can ingest that pesticide through preening. In one study, dermal exposure, including preening, was found to be a greater contributor to toxicological response from 8 to 48 hours post-spray than oral exposure in northern bobwhite exposed to simulated aerial crop applications of the cholinesterase-inhibiting pesticide methyl parathion (Driver, et al. 1991).

EPA did not assess exposure of birds and mammals through preening or grooming in the BE. We considered data regarding dermal toxicity and found this route to be a less sensitive endpoint than dietary exposure. However, the absence of an assessment from preening or grooming adds additional uncertainty to our analysis.

Inhalation

Exposure via inhalation can occur from spray droplets at the time of the application and volatilized residues under the crop's canopy. In a controlled study with the cholinesterase-inhibiting pesticide methyl parathion, inhalation was found to be the major contributor to toxicological response in the hours immediately following spray compared to other routes of exposure (Driver, et al. 1991).

For EPA's analysis, inhalation-based exposure values are calculated and used in the determination of off-site transport distances in both Step 1 and Step 2, if they represent the most sensitive exposure value. For the Step 2 probabilistic analyses, the exposure analysis is focused on dietary exposures. While dietary exposure is considered the most sensitive endpoint for our analysis of methomyl effects, the absence of an assessment of the contribution from inhalation exposure adds additional uncertainty to our analysis. Ingestion - drinking water

Terrestrial species may be exposed to pesticides in water consumed beyond what is ingested from food items. In the BE, pesticide dose in drinking water is estimated under the assumption that the animal is consuming 100% of its daily diet from an individual food item and 100% of the remaining water need from either puddles or dew. If the diet of a species includes multiple food items (e.g., yellow-billed cuckoo), drinking water rates for each of these food items is calculated, for dew and for puddles, independent of each other. This is a kind of "what-if" approach, where the question is: "What is the dose if the animal is consuming 100% of its diet as this single food item with residues representative of the treated field and 100% of its remaining water from either dew or puddles on the treated field?"

For EPA's analysis, exposure values based on drinking water are calculated and used in the determination of off-site transport distances in both Step 1 and Step 2, if they represent the most sensitive exposure value. For the Step 2 probabilistic analyses, the exposure analysis is focused on dietary exposures. While dietary exposure is considered the most sensitive endpoint for our analysis of methomyl effects, the absence of an assessment of the contribution from exposure from drinking water adds additional uncertainty to our analysis.

Estimated Environmental Concentrations (EECs) on Use Sites and from Offsite transport

For the overlap with species range, the BE considers the aggregate of the six years (2013-2017) of available CDL data for pesticide use categories to ensure the full footprint is captured for each use. For the Opinion, we bring forward the same analysis used in the BE. Terrestrial exposure concentrations are uniquely calculated for each species depending on relevant use overlap with the species range, application rates associated with these relevant uses and the dietary items, habitat, and obligate relationships for that species. To provide a bounding of potential terrestrial EECs used in the effects determinations, EECS were calculated for the range of application rates for methomyl (a minimum application rate of 0.45 lbs a.i./acre with 1 application per year and a maximum application rate of 0.9 lbs a.i./acre with 24 applications per year) and provided in the BE in Table 3-12. Table 3-12. The BE summarizes the mean and upper bound dietary-based EECs and the associated base model that is used. However, because of the multiple applications and persistence, individuals may be exposed multiple times during a year. While those exposures would be at lower concentrations (submaximal), they may be sufficiently high to cause adverse effects and contribute to risk. However, we do not have information to predict where and when multiple applications may occur.

Terrestrial EECs and overlap values for exposure via spray drift were generated in 30-m increments from use sites, up to 90 m from the application site, as this was determined to be the maximum distance at which effects occurred for terrestrial species. These estimates assume drift extends these distances off fields, and typically represents open areas with flat topography. Pesticides may drift farther in some instances. In other instances, drift may be minimized by application methods, timing, or landscapes that impede its movement (e.g., forest).

For all species, we assume spray drift will increase the area of overlap with the species range, with this assumption particularly important for species that are not anticipated to enter use sites, as it may represent the only exposure to methomyl that is likely to occur. However, it is important to note that spray drift areas from different uses can overlap with one another, or even overlap with use sites, depending on their proximity on the landscape. For this reason, combining areas from different uses where spray drift exposure could occur without accounting for this proximity could overestimate the total overlap with the species' range.

Chemical Persistence

Methomyl appears to degrade in soil with a metabolic half-life from 4.3 to 44 days in registrant-submitted studies depending on soil type, soil moisture, and temperature. The environmental fate of the major methomyl degradates methomyl oxime (S-methyl-N-hydroxythioacetimidate), acetonitrile, acetamide, and CO_2 are the following: Methomyl oxime (S-methyl-N-hydroxythioacetimidate) was detected at a maximum of 44% in an alkaline hydrolysis study. Acetonitrile was detected at a maximum of 66%, 40% and 27% in aqueous photolysis, soil photolysis, and aerobic aquatic metabolism studies, respectively. Acetamide was detected at 14% in an aerobic aquatic metabolism study. CO_2 was detected at 22.5-75% in aerobic soil, anaerobic soil, and aquatic metabolism studies. The only non-volatile degradate in the laboratory studies was methomyl oxime (S-methyl-N-hydroxythioacetimidate). It was present at high concentrations in an alkaline hydrolysis study but was only a minor degradate in the aerobic soil metabolism, anaerobic soil metabolism, photolysis, and aerobic aquatic metabolism studies. None of these major methomyl degradates identified in the environmental fate studies is of toxicological concern based on the available data. Values for foliar half-lives ranged from 1.2 to 2.7 days. In addition, for most registered uses of methomyl, either two or more applications per year are permitted, and a maximum of 32 applications for some crops (radishes in Florida). As a result, EECs at a given use site that are expected to result in adverse effects to species may persist days to weeks following an application, with the length of time depending on the food item, application rate, and number of applications. Alternatively, depending on the length of time between applications, species may experience multiple periods where methomyl residues on food items reach levels sufficient to cause adverse effects.

While chemical persistence is not explicitly incorporated into the analysis of terrestrial exposure (i.e., number of days that EECs may cause adverse effects), we have chosen to consider peak values as a way to capture the breadth of potential effects to species, as discussed above.

Based on methomyl's aerobic soil metabolism and aerobic and anaerobic aquatic metabolism data, methomyl is not considered persistent[17] in the environment, with half-lives on the order of days to weeks (representative[18] half-life values range from 2.5 to 52 days).

Mixtures

Pesticide mixtures can be divided into three categories: formulated products, tank mixes, and environmental mixtures. Formulated products are produced and sold as one product containing multiple active ingredients. We have the most confidence in species being exposed to these types of mixtures, as application of these products ensures that both active ingredients enter the environment at the same time. Formulated products containing methomyl have been identified as part of this action and are shown in Table 26. Tank mixes refer to a situation where the pesticide applicator applies multiple pesticides simultaneously at the use site. Unless explicitly prohibited on the pesticide labels, any two active ingredients may be combined in a tank mix. Though we have less certainty in these types of mixtures occurring, specific tank mixes are often described on product labels and their use may be encouraged to increase pesticide efficacy. Environmental mixtures result from unrelated pesticide use over the landscape and are typically detected in ambient water quality monitoring efforts. From monitoring efforts, we have high confidence that these types of mixtures occur. Monitoring data from state and federal agencies described in the BE and elsewhere have indicated that multiple pesticides often co-occur in aquatic habitats located throughout the United States. Studies conducted by the U.S. Geological Survey, under the National Water Quality Assessment program, have routinely detected the presence of multiple chemicals in surface water and groundwater samples.

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[17] Based on the Toxic Release Inventory classification system where half-lives greater than 60 days in water, soil, and sediment are considered persistent and half-life greater than 6 months are considered very persistent (USEPA, 2012a).

[18] Half-live values were calculated using the North American Free Trade Agreement (NAFTA) guidance in estimating degradation kinetics (NAFTA, 2012; USEPA, 2012b).

Table 26. Formulated products containing methomyl.

Product Name	Registration Number	Company name	Restricted Use Pesticide?	Active Ingredient(s)
GOLDEN MALRIN RF-128 FLY KILLER	2724-274	Wellmark	No	Methomyl (Z)-9-Tricosene
STARBAR GOLDEN MALRIN FLY BAIT	2724-274	Wellmark	No	Methomyl (Z)-9-Tricosene
METHOMYL 5G GRANULES	57242-2	GLADES FORMULATING CORPORATION	Yes	Methomyl
LANNATE SP	61842-52	Tessenderlo Kerley, Inc.	Yes	Methomyl
LANNATE SP INSECTICIDE	61842-52	Tessenderlo Kerley, Inc.	Yes	Methomyl
METHOMYL COMPOSITION	61842-53	Tessenderlo Kerley, Inc.	Yes	Methomyl
METHOMYL TECHNICAL	61842-54	Tessenderlo Kerley, Inc.	Yes	Methomyl
LANNATE LV	61842-55	Tessenderlo Kerley, Inc.	Yes	Methomyl
LANNATE LV INSECTICIDE	61842-55	Tessenderlo Kerley, Inc.	Yes	Methomyl
METHOMYL TECHNICAL	70552-2	Sinon Corporation	Yes	Methomyl
LURECTRON SCATTERBAIT	7319-6	Denka	No	Methomyl

				(Z)-9-Tricosene
ROTAM METHOMYL TECHNICAL	81598-9	Albaugh LLC.	Yes	Methomyl
METHOMYL TECHNICAL	81598-9	Albaugh LLC.	Yes	Methomyl
CORRIDA 29 SL INSECTICIDE	82557-2	Sinon USA, INC.	Yes	Methomyl
METHOMYL 29 SL INSECTICIDE	82557-2	Sinon USA, INC.	Yes	Methomyl
CORRIDA 90 WSP INSECTICIDE	82557-3	Sinon USA, INC.	Yes	Methomyl
METHOMYL 90 WSP	82557-3	Sinon USA, INC.	Yes	Methomyl
ROTAM METHOMYL 29LV INSECTICIDE	83100-27	Albaugh LLC.	Yes	Methomyl
ROTAM METHOMYL 90SP INSECTICIDE	83100-28	Albaugh LLC.	Yes	Methomyl
AX METHOMYL 90 WSP	89167-120	Axion Ag Products, LLC	Yes	Methomyl
AX Methomyl 29LV Insecticide	89167-91	Axion Ag Products, LLC	Yes	Methomyl

The EPA has indicated that the Denka company has submitted a letter with request to cancel the registration for the Lurectron Scatterbait as of May 2024. Officially, it is still registered until the cancelation process is complete. In addition, the EPA has issued a notice of intent to cancel the Methomyl 5G Granules product, and the company Glades Formulating Corporation has gone out of business. Officially, it is still registered as of June 2024, until the cancellation process is complete. As described in Appendix 4-2 of the BE, species and their habitats exposed to pesticide mixtures may be at greater risk of adverse effects than when exposed to single pesticides. Recent review articles indicate that additivity (i.e., concentration- or response-addition) is the appropriate default assumption when considering mixture toxicity. However, the magnitude of that increase is uncertain because the composition of mixtures and concentrations of pesticides and their degradates in the environment is usually not known.

Factors to Determine Percent of the Population Exposed – Terrestrial Species

Utilization of pesticide use site

Concentrations of pesticides on food items and contaminated media such as plants are generally higher on pesticide use sites than on adjacent areas contaminated only by off-site transport from spray drift. Individuals that are predicted to experience effects from pesticide exposure on use sites may have reduced effects, or in some cases no effects, from exposure to pesticide as a result of spray drift. For this reason, the tendency of individuals to enter or forage within a use site, when known, can affect the likelihood of exposure and effects. Species experts within Service field offices were asked to comment on whether species will enter, forage, roost, breed, pass through, or otherwise utilize pesticide use sites that overlap with the range of the species. Where this information was available, we incorporated it into the analysis to verify or limit potential exposure as appropriate. For example, if a species may breed or forage on a use site, exposure was considered both on the use site and as a result of spray drift. If a species is only likely to travel through a use site, we primarily focused our analysis on exposure from spray drift. If a species was deemed unlikely to enter a use site, we did not consider effects from on-field exposure. Where data were lacking on whether use sites would be avoided, we assumed that a species could enter, forage, roost, breed, pass through, or otherwise utilize sites of pesticide use based upon their location within the species range. More specific information regarding a species' behavior on or near use sites results in better exposure assessments and reduced need for conservatism.

Mobility of individuals

The percent of a population exposed to a pesticide may be influenced by the distance an individual travels to forage. As a default, we assume the proportion exposed is roughly equivalent to the percent of overlap between pesticide use sites and the species range. We may have more confidence in this assumption for species that have limited mobility compared to those with high mobility. For species that travel large distances to forage, this overlap is likely to be less predictive of pesticide exposure, depending on the distribution of use sites throughout the range. For instance, wood storks can travel large distances to forage, and use sites occur throughout their range such that any individual could access that landcover type. In these cases, we would have less confidence that the percent overlap equates to the proportion exposed, as individuals from outside the overlap area are likely to enter the area to forage. However, we would still consider and acknowledge that these use sites only represent a certain fraction of their range.

Determining Percent of the Population Exposed – Aquatic Species

Aquatic-Specific Exposure Factors

Aquatic species are likely to be exposed to pesticides that are deposited in surface waters through runoff and drift transport pathways. Our analysis focuses on exposure from contact with contaminated surface water. While dietary exposure may also be a relevant route of exposure, response data to the dietary exposure route is generally not available for these species or related surrogates. Furthermore, contact with surface water is expected to be the primary route of exposure for aquatic species and is likely to capture any effects that may occur from the dietary route. Consequently, exposure was only evaluated using surface water concentrations estimates derived by EPA in the BE.

Aquatic Habitats

Aquatic species depend upon a variety of aquatic habitats which vary in size, volume, flow, etc. To better estimate pesticide exposure in these different types of surface waters, ten generic habitat types were defined (Table 27): one to simulate aquatic-associated terrestrial habitats, three to simulate flowing waterbodies (habitats 2-4 in Table 27); three to simulate static waterbodies (habitats 5-7 in Table 27) and three to simulate estuarine/marine habitats (habitats 8-10 in Table 27). Aquatic-associated terrestrial habitats (habitat 1) include riparian habitats or other land-based habitats adjacent to waterbodies that may occasionally be inundated with surface water, provide habitat used by aquatic organisms and semi aquatic organisms, or influence the quality of the aquatic habitats.

The Service identified the representative aquatic habitats uses by each listed species. A single species may occur in a range of habitats represented by multiple aquatic habitats. The low flow/low volume habitat is intended to represent habitats with flow rates occurring of 0.001-1 m^3/second including springs, seeps, brooks, small streams, and a variety of floodplain habitats (oxbows, side channels, alcoves, etc.). The high flow water body flow rates are representative of small to large streams (1-100 m^3/second) and the highest flow aquatic habitats (larger volumes and flow rates exceeding 100 m^3/second) correspond with larger riverine habitats. Aquatic habitats that are relatively static, where flow is less likely to substantially influence the rate of pesticide dissipation, are characterized by examples of low volume habitats (volumes <100 m^3) such as vernal pools, small ponds, floodplain habitats that are cut off from main channel flows, and seasonal wetlands. Aquatic habitats with intermediate volumes (100 – 20,000 m^3) correspond with many ponds, vernal pools, wetlands, and small shallow lakes, and the high volume static aquatic habitat represents larger volume habitats (>20,000 m^3) such as lakes, impoundments, and reservoirs. The aquatic habitats represented by intertidal near shore, sub tidal near shore, and offshore marine (as described in Table 26) were designed to characterize marine habitats. The EPA does not currently have models designed to estimate EECs for the estuarine/marine systems. Therefore, surrogate freshwater flowing or static systems were used to evaluate exposure in estuarine/marine habitats as appropriate.

Table 27. Generic aquatic habitats (BE Table 1-7).

Generic habitat	Depth (meters)	Width (meters)	Length (meters)	Flow (m3/second)
1 – *Aquatic-associated terrestrial habitats (wetland)*	NA	NA	NA	NA
2 – *Low-flow*	0.1	2	length of field[19]	0.001
3 – *Moderate-flow*	1	8	length of field	1
4 – *High-flow*	2	40	length of field	100
5 – *Low-volume*	0.1	1	1	0
6 – *Moderate-volume*	1	10	10	0
7 – *High-volume*	2	100	100	0
8 – *Intertidal nearshore*	0.5	50	length of field	NA
9 – *Subtidal nearshore*	5	200	length of field	NA
10 – *Offshore marine*	200	300	length of field	NA

Aquatic Exposure Modeling and Exposure Estimates

The EPA derived estimates of pesticides in surface waters and benthic sediment pore water by incorporating the aquatic habitat parameters (Table 27) into exposure models. Combinations of several fate and transport models including the PRZM5, the VVWM, and AgDrift (version 2.2.1) were used to estimate concentrations in aquatic habitats of variable sizes and flow rates representative of habitats used by listed species (BE Chapter 3). The methodology used inputs consistent with application requirements specified on product labels. Additionally, inputs representing application site characteristics (e.g., meteorological conditions) were selected at the HUC2 regional scale (Figure 8) to generate geographically specific EECs (USEPA 2017).

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[19] length of field – The habitat being evaluated is the reach or segment that abuts or is immediately adjacent to the treated field. The habitat is assumed to run the entire length of the treated area. Exposure concentrations in surface water and benthic sediment pore water, downwind from the chemical's use are evaluated using AgDRIFT and AGDISP, as previously described in Section 1.5.1.1.c.1 NA indicates that concentrations were not calculated.

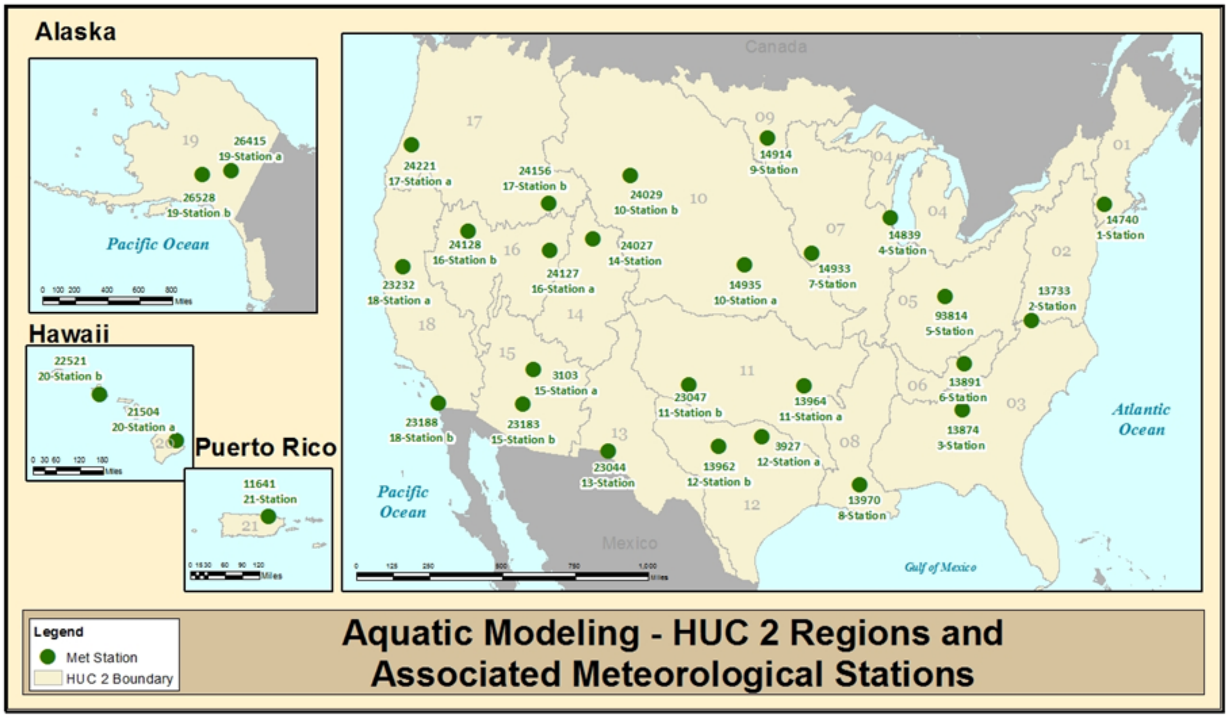

Figure 8. Hydrologic Unit Code (HUC) 2-digit Regions and Associated Metrological Data.

Estimated Environmental Concentrations (EECs) for Aquatic Habitats

We delineated aquatic species ranges by HUC12s (subwatershed) and based exposure of aquatic species to methomyl on the overlap of methomyl use sites with the HUC12(s) that comprised their ranges. For the static-water habitats and the smallest flowing-water habitats within HUC12s, EECs are calculated for each overlapping use site (e.g., corn, wheat). We modeled each use as if the water body was immediately adjacent to the site (i.e., edge of field). However, the medium and large streams/rivers) were modeled at the subwatershed/HUC12 scale (USEPA 2017). The EECs derived from the PWC modeling based on maximum labeled rates included in the master use summary document, by HUC 2, are summarized for the various aquatic habitats in Table 3-5 and Table 3-6, for water column and pore water, respectively in the BE. The complete set of modeling inputs and results are available in Appendix 3-1 of the BE.

<u>Proximity to Pesticide Use Sites</u>

The likelihood that individuals will be exposed to methomyl will be influenced by many factors including the proximity of populations to pesticide use sites. For our analysis, we consider that exposures may occur if pesticide use sites overlap with HUC12(s) that comprise the species range. For some species, there may be specific information regarding the location of populations within their range (i.e., occurrence in specific waterbodies or waterbody segments). Further spatial refinement of species locations within their range, such as narrowing the number of HUC12s or evaluating the proximity to use sites within HUC12s, was generally beyond the scope of this assessment. Therefore, we assumed the species would occur throughout its range (i.e., in all HUC12s), and individuals to be uniformly distributed within and between HUC12s.

For species that occur in waterbodies of low flow and volume or large volume, under the uniform distribution assumption, we approximate the percentage of individuals in the population that are likely to be exposed by the percent overlap of pesticide use sites within the range. For species that occur in medium and large rivers we assume 100% of individuals in populations within HUC12s (where there is overlap with pesticide use sites) are assumed to be exposed because the exposures in these aquatic habitats were modeled at the subwatershed scale.

Mobility of Individuals

Some aquatic species, including many aquatic invertebrates and narrow endemic fish species, do not (or cannot) move large distances and are more likely to be exposed as a result of localized pesticide use. However, highly mobile or migratory species, such as anadromous fish (e.g., Atlantic salmon and Atlantic (Gulf) sturgeon), travel great distances and individuals could be exposed to pesticides from multiple use sites along the migratory corridor. Alternately, these species may be absent from any particular area at the time of pesticide use. For these reasons, the percentage of the population exposed may be lesser or greater than would be predicted based solely on overlap of use sites in individual HUC12s within the range depending on the presence of the species.

Probabilistic Aquatic Exposure Assessment

As mentioned above, we carried forward EECs generated for the BE into the Opinion. However, in the Opinion, we report aquatic exposures probabilistically for all uses except fly-bait applications. The probabilistic method we use captures the variability in EECs derived by incorporating geographically specific estimates that are accounted for from two sources: (1) the occurrence of pesticide use sites within the species range (six-year data set), and (2) daily precipitation (30-year data set). In brief, this analysis was based on the 30-year annual maximum EECs from the 30-year annual time series (1-day time step) generated for each pesticide use/scenario/HUC2/aquatic habitat combination. The 1-in-15-year exposure concentrations are estimated using the daily time series of estimated concentrations from 30-year PRZM5/VVWM simulations, to be consistent with the length of the action (15 years), based on the registration review cycle.

Plant-specific Exposure Factors

Based on our review of the possible effects of the action to plant species covered under this consultation, we assume reductions in pollinators and reductions in seed dispersers would affect reproductive success. The latter also corresponds to “indirect effects” in risk assessment terminology. While such indirect effects are also anticipated for other taxa, we discuss the potential exposure of insect pollinators in greater depth in this section due to the high toxicity of methomyl to potential insect pollinators and the dependence of many plants on insect pollinators for successful reproduction.

Routes of Exposure for Pollinators

Insecticides help to rid gardens, agricultural areas, forests, nurseries, and other areas from the harmful effects of unwanted or pest insects. However, insecticides also impact non-target insects with effects dependent on the timing of application (seasonal, daily, and temporal), environmental factors, and concentration of the chemical, among other factors. Pesticides, combined with other contributing stressors, is a cause for decline in bee populations (Le Conte, Ellis and Ritter 2010, Maxim and van der Sluijs 2010). Bees (superfamily Apoidea) are the most dominant animal pollinator and prominent agricultural crop pollinator in North America (Cutler, et al. 2014), making bees the focus of most literature review and studies. Honey bees (*Apis* species) are the most well-studied as they are the pollinator to major crops and are managed by humans (primarily nonnative honey bees). However, non-*Apis* bees may also be exposed to methomyl but are different from honey bees with differing routes of exposure. Most non-*Apis* bees are solitary nesters and use soil and/or vegetation for nest construction, or to nest in the soil (Michener 2007).

Secondary routes of exposure can affect both social pollinating adults and offspring of honey and bumble bees if the pesticide is brought back to the hive or nest, deposited in food, or transferred to other individuals (Cutler, et al. 2014). The main pathway of exposure is transfer of residues in pollen or nectar into hives or nest (Cutler, et al. 2014). Since some plants have flowers that provide pollen or nectar for several days after opening, these present the most susceptible source for oral exposure for pollinators.

Little information is available on the effects of ground nesting bees to pesticides or simply nesting habits of these bees within agricultural ecosystems (Julier and Roulston 2009, Kim, Williams and Kremen 2006, Wuellner 1999).

Water can also be a significant exposure pathway for pollinators. Bees typically rely on wet foliage, puddles, soil saturated with water, or other small areas for water (Winston 1987, Samson-Robert, et al. 2014, Gary 1975). The amount of water consumed by a honey bee varies by life stage and role within the hive. Water requirements within a honey beehive vary depending on outside air temperature, humidity, and amount of brood (Thompson 2010).

Exposure Pathways for Cave Species

Listed cave-dwelling organisms consist of terrestrial invertebrate species (cave arachnids and beetles), crustaceans (cave amphipods), and fish. These species may be exposed to pesticides in water from over land flow or leaching from soil from agricultural practices over or near lava tubes, sinkholes, karst systems, or other porous features near the surface of cave habitats. However, the environmental fate, transport, and physicochemical properties of methomyl are such that it is not mobile enough in soil matrices or water, or persistent enough in the environment at levels toxic enough from run-off of fields after application to impact cave species or contaminate their dietary items outside of caves. This is due to the time scale of recharge of karst cave systems, or the process of aboveground water reaching the groundwater supply. This will often take several days to weeks to months, at which point we expect methomyl to be degraded and no longer present in the water that enters the cave.

Methomyl may enter the environment via spray and spray drift as well as run-off onto soil, foliage, and/or water. Methomyl is also very soluble ($5.5x10^4$ mg/L) and we know that its presence in run-off water has been detected from field application monitoring studies (aquatic residue monitoring studies for various use patterns were conducted in different states: sweet corn in Illinois and Georgia; apples in Michigan; lettuce in Florida; and cantaloupe in California.

These studies are briefly summarized in the BE chapter 3). Methomyl was also found in aquatic environments adjacent to treated fields in all five studies at maximum concentrations ranging from 1.7 up 175 µg/L. Runoff water leaving treated fields had concentrations as high as 1,320 µg/L).

However, the aerobic soil metabolism, and aerobic and anaerobic aquatic metabolism data indicate methomyl is not considered persistent, with half-lives on the order of days (2.5) to weeks (52) depending on soil and water conditions. Under anaerobic conditions, degradation of methomyl is likely faster than under aerobic conditions (Bromilow, et al. 1986). It is not stable to hydrolysis at pH levels (6-8) that would be environmentally relevant to listed species and is not persistent in environments where microbial activity is present, which is also relevant to listed species as most natural environments contain high microbial activity. In addition, the maximum depth of leaching for methomyl from terrestrial field dissipation studies (discussed more in depth below) is 30 inches and thus methomyl is not likely to reach groundwater. Studies investigating impacts of methomyl to ground water were conducted using Lannate L, a formulated product of methomyl, applied to a sweet corn field in Cook County, Georgia. Methomyl was not detected in ground water except at 12-foot depth suction lysimeters at low concentrations (0.943 µg/L).

Karst systems are known to have enhanced porosity and permeability and are therefore susceptible to pesticide contamination that could be present in run-off water (Vesper, Loop and White 2000). While run-off water is likely to contain methomyl from field applications of methomyl, it is not likely to reach karst systems from the surface waters and enter the subterranean habitats where many listed cave species reside (cave arachnids, cave crustaceans, and cave fish) because methomyl is not likely to persist very long (as mentioned above) after it has traveled from the surface and into karst cave reaches.

Lava tubes are a different type of cave system formed from lava flow and present in Hawai‘i where there are two listed cave invertebrates (Kaua‘i cave spider and Kaua‘i cave amphipod). The water table in lava tubes generally lies much deeper and below the lava layer (Kiernan and Middleton 2005) and therefore is not likely to retain methomyl from surface flow. The main energy sources in Hawaiian lava tubes are plant roots, especially Ohia-lehua, slimes deposited by percolating ground water, and animals that die and get washed in or fall in (Howarth, 1978). Plants are not adversely impacted by exposure to methomyl and surface-derived nutrients from carcasses are also not likely to accumulate or be adversely impacted by methomyl.

Methomyl is predominantly present in the water column and to a lesser extent, bound to sediments based on measured octanol-water partition coefficient ($K_{ow} = 1.2$) and K_{oc} values (36-72). These values indicate exposure to sediment-dwelling organisms is likely to occur but to a lesser extent as compared to organisms in the water column. The low octanol/water partition coefficient also suggests that the chemical will have a low tendency to accumulate in aquatic and terrestrial organisms and is further supported by bioconcentration studies with results indicating this does not occur (P. Howard 1991). Thus, we do not anticipate water entering cave systems will contain methomyl because it will degrade before it enters the cave depths, nor will it accumulate in organisms that cave species may use as prey inside cave systems. In addition, it will not accumulate in terrestrial organisms that may be external food sources for cave species.

Cave dwelling organisms may also feed on dietary items near the cave entrance. Many of the listed cave dwelling species rely on surface-derived nutrients that include leaf litter fallen or washed in, animal droppings, and animal carcasses. Several studies cite that nutrients in cave ecosystems are derived from exterior sources (Poulson and White 1969, Howarth 1983, Culver 1986); (Howarth 1983)), particularly from organic material washed in or brought in by animals. Bats are usually the major source of these nutrients, as well as the major source of contaminants (Kunz 1982).Pesticides can be introduced into caves by bats from their exposed carcasses that decay in caves or from bats defecating in caves (McFarland 1998, Sandel 1999, Land 2001, Eidels, Whitaker and Sparks 2007);. Bats within a population/colony may consume pesticide-exposed insects while foraging in or near use areas and guano accumulated from multiple bats within the cave will reflect that exposure. However, we do not anticipate that cave-dwelling organisms that forage on guano will be exposed to methomyl as it does not bioconcentrate or bioaccumulate.

Examples of studies showing dissipation of methomyl from treated fields indicated that terrestrial field dissipation half-lives from the surface soil ranged from 4-6 days in Mississippi to 54 days in California using methomyl applied to cabbage. The differences in dissipation between the two sites can be explained by soil moisture content, which may affect the level of biological activity, (moisture content varied between the two sites and ranged from 2.5% to 17% in the California soils and averaged 16% over the first 15 days in the Mississippi soils). The Mississippi site received more rainfall, which may have led to more leaching out of the surface. In both studies most of the methomyl residues were found in the upper 30 cm of soil. Thus, providing further evidence that methomyl is likely to dissipate before it reaches cave depths regardless of the cave type (karst or lava tube) and depends on the soil moisture content.

In summary, we do not anticipate that direct application or drift from methomyl would be likely exposure pathways for cave species when they are in subterranean habitats. Nor do we anticipate cave species would be exposed to methomyl from contaminated food sources entering the cave or leaching through porous substrate, such as karst or lava tubes.

Usage Analysis

The overlap information above describes the footprint of the methomyl use based on the product label and any off-site transport. We apply usage data to describe how the pesticide has been applied in the past to the use sites based on available data sources. The key difference between use and usage is that use data extends to all methomyl uses authorized by EPA, whereas usage refers to how methomyl has been applied on the landscape. To determine effects to listed species, we employ usage data to refine the scope of analysis from any area where methomyl is authorized to be applied, to those areas where methomyl applications are reasonably certain to occur. While we recognize that past usage data may not fully predict future usage, we believe this information better informs where we would expect usage to occur in the future and provides more context for our assumptions related to uncertainty.

As part of its BE and supplemental submissions, EPA provided the following usage information:

- National and State Use and Usage Summary for Methomyl

- USDA Census of Agriculture (CoA) data for CONUS species
- USDA Census of Agriculture data for Hawaiʻi and Puerto Rico
- California Department of Pesticide Regulation Pesticide Use Reporting data

We briefly describe each data source and how it was applied in our analysis below.

EPA's Methomyl National and State Summary Use and Usage Matrix (SUUM; methomyl BE Appendix 1-4)

EPA obtains the data in their Use and Usage Summary for agricultural crops from USDA, the state of California, and a commercial source (Kynetec), as described in more detail in the BE. EPA's analysis of this data indicated there has been an overall decreasing trend in agricultural usage of methomyl between 2009 – 2017, with pounds applied and total acres down by approximately 70% during that period. Similarly, for the period 2013 to 2017, pounds of methomyl applied have decreased by 26% while total acres treated has decreased by 33%.

Most of the data for states outside California describing past methomyl agricultural usage are from the proprietary source Kynetec. According to materials provided by the company, Kynetec data is "designed to address market questions asked most often by senior executives, and those involved in product development, sales, and marketing." Surveys are designed to reach a particular percentage of the total crop grown at a national level, though statistics are reported at the state and Crop Reporting District (CRD) level when sample size is adequate. The data provided to the Service is lacking the statistical foundation to understand the robustness at the state level or any geographic specificity at the sub-state level. Neither EPA nor Kynetec was able to provide us this information (e.g., how many applicators responded to the survey, how many acres are represented by the survey at the state level), nor any standards used to determine an adequate sample size at these levels, nor the minimum threshold required for reporting these values. Our understanding is that this varied on a case-by-case basis, according to the surveyor, crop, and state.

These data are provided at the state level and indicate how many acres of a crop has been treated with methomyl over a 5-year period (2013 – 2017 for Kynetec data). Acres that are reported as "treated" are compared to the total number of acres grown for each crop at the state level, to produce a "percent crop treated (PCT)" value. EPA provided the Service with PCT values at the national and state level (mean, minimum, and maximum) over a 5-year period. The data are not comprehensive of all crops for which methomyl is registered, and do not address every state in which surveyed crops are grown. In addition, with no indication of the robustness of the agricultural data provided by EPA at the state level, there is particularly high uncertainty associated with this dataset and we are unable to evaluate how representative these data are of past usage in these states. However, in a previous analysis of usage data, we did not find other data sources that would broadly inform our understanding of agricultural usage of pesticides on a nationwide scale (US FWS 2022a). As such, we consider these data as our primary source of agricultural usage data for all CONUS states except for California, as described further below. We employed the conclusions from our 2022 analysis (US FWS 2022a)to inform our application of these data to our analysis of methomyl usage in these states. In short, our analysis of various data usage sources led us to adopt a conservative approach when applying this survey data to better ensure that we capture the extent of usage occurring within states. Specifically, we consider the percent of a species' range treated with methomyl using EPA's "upper maximum" scenario, which compares the total number of acres treated within a state to the total number of acres in the range of the species (see BE Appendix 1-7). In addition to using the maximum yearly usage across 5 years, this method assumes a 2.5% PCT for crops that were surveyed and no usage was reported to buffer against the uncertainty associated with these surveys and low usage estimates.

Methomyl usage data are not available for Pacific and Caribbean islands, including Hawaiʻi and Puerto Rico. We discuss our methods for estimating usage on these islands below.

USDA's Census of Agriculture (CONUS species)

USDA's Census of Agriculture (CoA) is a complete count of United States farms and ranches that includes any plot of land, whether rural or urban, if $1,000 or more of agricultural products were produced and sold, or normally would have been sold, during the census year. The Census of Agriculture is conducted once every five years, looks at land use and ownership, producer characteristics, production practices, income, and expenditures. Response to CoA is required by federal law and is therefore considered mandatory reporting data. As part of the data requested from operators, respondents report the number of acres treated with insecticides that year. In summarizing the data collected, USDA analyzes and reports results at the national, state, and county level.

In its analysis of CONUS species, EPA used the 2017 CoA data to estimate the number of acres treated with insecticides within counties that overlapped with the ranges of listed species, and then compared that with the total number of acres in the species' range. EPA did not provide estimates of the percent of the range treated for every CONUS species, rather they reported when the number of total acres treated within the range of the species was <5% of its range. As this percentage reflects usage of all insecticides, and not just methomyl, we consider this as an additional line of evidence, when appropriate, as an upper bound for methomyl usage.

USDA's Census of Agriculture for Pacific and Caribbean Islands

For Caribbean or Pacific islands (including Hawaii, Puerto Rico, the U.S. Virgin Islands, the Commonwealth of the Northern Mariana Islands (CNMI), Guam, and America Sāmoa), we reviewed available usage data and concluded that there are no comprehensive, chemical-specific usage data that are suitable for incorporating quantitatively. In the absence of methomyl specific usage data, we consider CoA data provided by EPA exclusively for these islands to define the proportion of agricultural areas where insecticides may be applied. These data are reported at the county level for Hawaiian Islands (i.e., island-wide) from the 2017 report and are available from the islands of Hawaiʻi (35% of crops treated with insecticide), Honolulu (45%), Kauaʻi (8%), and Maui (16%). We extrapolate these data to other islands in the region, and where appropriate (e.g., species with more spatially refined range maps), we use these data as an additional exposure modifier to estimate the extent that a species' range is likely to be treated with insecticides. For Puerto Rico, data are reported at the municipality level from the 2018 report and range from 20-70% of crops treated with insecticides across 60 municipalities. We use these data broadly as confirmation that insecticide usage occurs on these islands, with methomyl presumably among these insecticides. In all cases, which we consider these values an upper bound for methomyl usage.

For the Hawaiian Islands, we note that PCT values differ from those reported in our 2022 Malathion Opinion (US FWS 2022a) for the same CoA census year. In addition to separating the data by island, in providing these values, EPA considered a more conservative value for the total cropland acres used in the derivation of the PCT to exclude more areas not considered to be agricultural lands. This generally resulted in a higher percentage of crops treated with insecticides. We adopt EPA's approach moving forward. However, given our qualitative consideration of these data in our Malathion Opinion (US FWS 2022a) as evidence that insecticides have been used on these islands, we note that use of this methodology would not have changed our evaluation of any listed species considered in that Opinion.

California Department of Pesticide Regulation Pesticide Use Reporting (CalPUR)

In California, annual reporting of pesticide usage is required for all agricultural and certain non-agricultural uses. California Department of Pesticide Regulation maintains a highly robust dataset of Pesticide Use Reporting (CalPUR). For the purposes of reporting, agriculture is broadly defined and includes usage on parks, golf courses, cemeteries, rangeland, pastures, and along roadside and railroad rights-of-way. Unlicensed, non-professional, residential pesticide applications around a home or garden are not required to be reported, though licensed professional pesticide applications in or around the immediate environment of a household are reported as non-agricultural use (usually "structural pest control" or "landscape maintenance"). Agriculture pesticide usage is reported per square mile and non-agricultural usage is reported at the county level. Information is publicly available and can be downloaded from their website[20]:

Because of the robust nature of this data set, we exclusively apply CalPUR data to estimate agricultural usage for species wholly within California, based on information provided by EPA (US EPA 2024a). For these species, EPA used a three-tiered approach to characterize potential exposure of Service listed species to methomyl, calculating the extent that each species' range overlapped with any pesticide usage, any insecticide usage, or methomyl only usage for the years 2011 - 2021. We used the maximum yearly value to estimate future usage for these species, as described further in (US EPA 2024a). In general, we considered the methomyl-only overlap in our species-specific analyses. This value represents high maximum single year overlap of treated areas with the species' range over the 10-year period. However, in instances where the sample size is very small (there are few pesticide reporters within the range), this value will have greater uncertainty and we may consider one of the higher tier values reported by EPA, such as usage of all insecticide with the range. This value is considered a more protective estimate as it is likely to account for the possibility that users may switch their insecticide choice to methomyl within the time frame of the registration review. The overlap metric that considers any pesticide usage within the range is the most conservative value provided by EPA and will likely overestimate

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[20] http://www.cdpr.ca.gov/docs/pur/purmain.htm

methomyl usage as it includes usage from other pesticide classes such as herbicides and fungicides.

Federal Lands

Federal lands cover about 640 million acres, which equates to 28% of land in the United States Of these federal lands, 65% are managed by DOI agencies, 30% by the U.S. Forest Service (USFS), 2% by the Department of Defense, and 3% by other federal agencies (Congressional Research Service 2020). DOI land management agencies (the Service, National Park Service, and Bureau of Land Management) and the U.S. Forest Service each employ designated pesticide coordinators, provide policy and direction on pesticide use, have a process in place to review and approve pesticide use proposals, and maintain reports on usage. Similarly, the Armed Forces Pest Management Board (AFPMB) recommends policy, provides guidance, and coordinates the exchange of information on all matters related to pest management throughout the Department of Defense (AFPMB 2020).

We expect pesticide use on federal lands for a variety of reasons, including invasives control and the protection of human health. Methomyl is only registered for use on agricultural crops, thus limiting the scope of its use in these areas. While we recognize that some federally managed lands may contain agriculture, we expect it will be a small percentage and that methomyl usage will be limited. For instance, cooperative agriculture is a long-standing practice on national wildlife refuges in which the Service partners with farmers to meet wildlife management objectives. A search of the Service's Pesticide Use Proposal System database indicated that no requests for methomyl usage or subsequent applications of methomyl occurred between the years 2013-2023. As such, we anticipate methomyl usage in these areas will continue to be minimal, if at all, as we do not have any information suggesting that future usage is expected to increase. Where information suggests that agriculture may be present in other federally managed lands within a species range, we consider this on a case-by-case basis. Where no information indicates that agriculture represents a significant influence in these areas, we assume that use of methomyl on federal lands will be minimal, at most, over the duration of the proposed action, and only occur in very localized areas.

CUMULATIVE EFFECTS

Cumulative effects are defined in ESA section 7 implementing regulations as "those effects of future State or private activities, not involving federal activities, which are reasonably certain to occur within the action area of the federal action subject to consultation." (50 CFR 402.02). Cumulative effects are considered broadly in this Opinion, due to the national scope of the action. More refined species-specific information on cumulative effects is also found in the species accounts of the Integration and Synthesis summaries in Appendix K of this Opinion. Future federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the ESA.

Declines in the abundance or range of many threatened, endangered, and other special status species are attributable to various human activities on state or private lands. We anticipate human population expansion and associated infrastructure, commercial, and private development will occur in the action area via various state and private actions. Such activities will likely include, but are not limited to:

- water use and withdrawals (e.g., water retention, diversion, or dewatering of springs, wetlands, natural and artificial impoundments, and streams);
- land and water development including excavation, dredging, construction of roads, housing, and commercial and industrial activities;
- mining and mineral extraction activities;
- recreational activities;
    - expansion, or changes in land use for agricultural or grazing activities, and other land uses including alteration or clearing of native habitats for domestic animals or crops; and
    - inadvertent introductions of non-native plant, wildlife, or fish or other aquatic species, which can alter native habitats or out-compete or prey upon native species.

All manner of development and competing use projects and activities (as above) are likely to continue in many areas, resulting in clearing, addition of impervious surfaces, and introductions of non-native species. Similarly, the incremental effects of climate change from such activities are anticipated to continue and intensify over the course of the proposed action. Some examples of such effects include, but are not limited to, more extensive and severe droughts that reduce the extent or quality of aquatic habitats, more extensive and severe wildfires that impact habitat more intensely, alterations of local temperature regimes that alter vegetation and water availability and vegetation composition. We expect these activities to result in various impacts to water quality (degradation, as with increased pollutants), habitat quality (loss or degradation), and other negative effects to listed species and their critical habitats. In some cases, increased pesticide use, including those in addition to methomyl, may occur to address new or emerging pest pressure (e.g., mosquitoes and other pests) in agricultural and non-agricultural settings. We anticipate some use of pesticides, including those in addition to methomyl, may be used directly or indirectly to benefit listed species or their critical habitats. For example, we anticipate future pesticide use to eliminate or reduce competing or predatory species within a species' habitat. While we are not aware of any such proposed projects at this time that would use methomyl to specifically benefit listed species, we do anticipate that methomyl or other pesticides will be used in the action area for this purpose over the life of the proposed action. Where implemented with appropriate avoidance and minimization measures to reduce the potential for lethal, sub-lethal, and indirect effects to listed species and their critical habitats, such projects could improve habitat conditions, thereby benefitting the species. However, in the absence of specific information for such activities, or for sufficient avoidance and minimization measures for other pesticides, we anticipate listed species will continue to be impacted as described previously in the *Environmental Baseline* section of this Opinion.

We also anticipate that conservation actions, such as habitat enhancement and restoration activities, will be undertaken in accordance with regional plans, recovery plans, and other planned or ongoing efforts. Where implementation is undertaken and successful, these activities are likely to benefit certain listed species and their habitats, food bases, hosts, pollinators, and other related species to varying degrees.

Given the broad geographic extent of the action area, many of the activities mentioned in the paragraphs above are expected within the ranges of various federally listed wildlife, fish, and plant species, and could contribute to cumulative adverse, and in some cases beneficial, consequences to the species within the action area. We anticipate that species with small population sizes, high degrees of endemism or limited distributions, or slow reproductive rates will generally be more susceptible to cumulative effects than species with greater resilience and redundancy to stochastic events (i.e., via multiple stable or increasing populations). For example, narrow endemics confined to specific habitat locations may experience habitat degradation that in turn results in reductions in individuals or even localized extirpations. Where such a species is unable to recolonize or repopulate the habitat, species-level declines would be expected. Species with single or small numbers of populations may struggle to maintain sufficient numbers of individuals to persist where cumulative effects result in loss of individuals or habitat degradation. Designated and proposed critical habitats with essential physical and biological features that are affected by these activities may also experience varying levels of degradation or improvement from these activities.

INTEGRATION AND SYNTHESIS

In this section of the Opinion, we consider whether the proposed action is likely to jeopardize any of the proposed, candidate, or listed species considered in this consultation. We also consider whether the proposed action is likely to destroy or adversely modify critical habitat as a whole for the conservation of a listed or proposed species. In the *Integration and Synthesis* section, we consider the effects of the proposed action in the context of the status of the species and critical habitats (as appropriate), the environmental baseline, and cumulative effects. The first section below is a review of the overall considerations for the Opinion. The next section provides a brief summary of the *Environmental Baseline*, *Status of the Species and Critical Habitat*, *Cumulative Effects* (together “Background Information”), and *Effects of the Action* sections. The final sections provide an overview of our approach to the integration and synthesis along with determinations and rationales for our Opinion for each plant and animal species and critical habitat, presented by taxa group and habitat group, and further discussed in Appendix C (for each species) and Appendix D (for each critical habitat designation), as applicable.

Overall Considerations for the Opinion

The proposed action is the registration review of methomyl, which authorizes all the uses of the pesticide per the products labels. The agricultural uses of methomyl are mostly limited as an authorized Restricted Use Pesticide. The non-agricultural use of methomyl (i.e., fly bait) is not a Restricted Use Pesticide. As the proposed action is the approval of labels containing the active ingredient methomyl, once approved, these labels become the law and are legally enforceable. The proposed registration review of the pesticide authorizes use of the pesticide on any of the crops or land categories described previously, with labels specifying one or more uses, associated restrictions, and guidance for that use. Proposed registration review labels have guidance that generally use terminology considered subjective and do not serve as enforceable restrictions. Some labels also include recommendations for tank mixtures. Tank mix recommendations may specify other ingredients that can be added to increase efficacy, such as surfactants, emulsifiers, oil, or salts, or may include another product with a different active ingredient. Listed species (as well as other species and habitats on which they depend) and their critical habitats exposed to pesticide mixtures may be at greater risk of adverse effects than when exposed to single pesticides, as described in the *Effects of the Action* section of this Opinion.

We and EPA are aware that there are often general trends and patterns related to agriculture, throughout the action area. We understand the most recent available land use data is a reasonably good indicator of present land use or land uses over the next few years or decades. While this information may suggest where pesticides such as methomyl may be applied in the future, we also recognize that land uses and pesticide usage may change over time due to a variety of often unforeseeable factors, such as future market forces, pest pressures, individual grower preferences and decisions, development and other land use changes, as well as changes in environmental conditions such as drought, floods, and maximum/minimum seasonal temperatures (e.g., unanticipated heat waves or freeze/frost events). We have incorporated these considerations by using a refined overlap analysis that considers use sites (by land use type) with labeled uses specific to methomyl, and by calculating estimates of anticipated methomyl usage, as described previously in the *General Effects* section of this Opinion. We find pesticide usage datasets are collected for very different purposes than addressing the limits of overlap of methomyl usage and listed species and their critical habitats in the action area. However, we were able to use this information, with its inherent uncertainties and our assumptions, to better identify methomyl use sites and gauge anticipated usage that is reasonably certain to occur for all use categories throughout the action area over the 15-year duration of the proposed registration of methomyl. We anticipate this information is also likely to have some value in determining appropriate avoidance and minimization measures in localized areas where adverse effects to listed species would be anticipated.

We recognize that growers will ultimately choose when and where crops and other commodities will be grown, and that growers, various local jurisdictions, and other property owners will likely determine where pesticide applications are needed. The broad label language, as currently written, is thus likely considered an asset for stakeholders to allow for greatest flexibility of use. However, we do not anticipate that methomyl will be used in all the areas it is authorized to be applied under the label over the duration of the proposed action. As we must also consider what effects are reasonably certain to occur, we considered the best available scientific and commercial data for usage to better predict the consequences from the proposed action.

For some uses, overlap of pesticide use sites with species ranges is extremely low (i.e., <1%). When considered in context, however, we emphasize that even where the overlap is extremely low, the very small degree of overlap may nonetheless lead to effects to the species, and if usage occurs in an area that is an important site for the species it may even have a disproportionate effect on the species. For example, certain areas may support important foraging, migrating, overwintering, or breeding habitat for a species. Where such habitat may be limited or of lower quality elsewhere within the range, pesticide applications in this area where the species is congregating or is otherwise dependent on could lead to species-level effects. Alternatively, the area of overlap may be an area that is rarely used by the species in its range, either at all or during the time in which applications would occur. Thus, where overlap with species ranges and critical habitat appeared extremely low, we would still consider the value of that area to the species or critical habitat using geospatial data and species information. It was only when we had information that indicated there was no true overlap that these areas were not considered further in our analyses, based on a closer look at the geospatial data and species information. However, for many species, our analysis included an assessment of small areas of overlap with methomyl use when we could not refine and/or exclude these areas based on additional information. These small overlaps were still part of the analysis because no additional information was available to exclude them and exposure in these areas is still a concern for a species. Such an approach is appropriate when even extremely low levels of overlap may still be of concern for species.

The fly-bait methomyl use, as previously discussed in the *Description of the Proposed Action* section, is limited to around livestock animal and poultry premises, commercial structures, and enclosed commercial dumpsters. The fly baits can be used as a perimeter scatter bait, placed in bait stations (hung at least 4 feet high), or mixed with water to form a paste which can be brushed onto walls, windowsills, and support beams of outdoor livestock houses. The foot print for this use is limited in scope and not likely a significant exposure pathway of methomyl for listed species or critical habitat (see BE Appendix 4-5). The fly-bait also contains a fly specific pheromone, muscamone, which was shown to have no toxic effects at the highest doses tested for studies on birds, fish, mammals, and freshwater invertebrates (ACC 232017, 232388, 229393, MRID 41785403, 41785404, 00070475, 00007196, 00007036, 00119133). The listed Delhi Sands flower-loving fly is associated with arid, sandy habitats, including dune systems of inland desert valleys, rivers, deltas, and beach strands. The Delhi Sands flower-loving fly is generally found in areas containing Delhi fine sands soil type and is only known from Riverside and San Bernardino Counties, with most occupied habitat located within a limited area of southwestern San Bernardino County (USFWS 2021). In addition, the three listed Hawaiian picture wing flies (*D. mulli, D. digressa, and D. heteroneura*) are found on the Big Island of Hawaiʻi in mesic to wet montane environments in different forest reserve units (South Kona Hakalau, Kukuiopaʻe , ʻŌlaʻa Forest Reserve, Moanuiahea pit crater on Hualalai, Papa in South Kona, and Manukā Natural Area Reserve) within and near Hawaiʻi Volcanoes National Park. Methomyl exposure from fly-bait applications is not likely within the range of any of these listed fly species as their habitats are not located near livestock facilities, thus these species are not likely to be impacted by the fly pheromone fortified methomyl fly bait.

Overview of Integration and Synthesis Analyses

We considered the consequences to candidate, proposed, and listed species from the proposed action in the context of the species background information (i.e., *Status of the Species*, *Environmental Baseline*, *Cumulative Effects*, and when applicable, *Designated Critical Habitat*). Plant species were grouped by life history categories, while animal species were evaluated individually or by sub-groups. While we recognize the species in this Opinion have variable life histories, distributions, recovery needs, and responses to the proposed action, as we reviewed the background information about the species and the anticipated consequences of the proposed action, we observed patterns in both species considerations and pesticide exposure that helped us sub-group terrestrial and aquatic animal species for the initial stages of our analysis. Additionally, where relevant taxonomic groupings exist (e.g., terrestrial vs. aquatic snails, families of mussels, sea turtles or marine mammals), or habitat groups (e.g., cave systems), we considered them simultaneously in the integration and synthesis analysis to ensure better consistency across species. The information described above for each species, or group of species was briefly considered to determine how and to what extent the consequences of the proposed action would affect the listed resources, per the language of the labels and in consideration of anticipated usage within the species range. We found that taxa, habitat, or other assessment groupings were helpful in both organization and in conducting or describing parts of our analyses and associated rationales for our conclusions. However, we also included information specific to each species or critical habitat in our analysis.

The rationale for our conference opinion[21] for proposed and candidate species and proposed critical habitat designations are included in this section and its appendices. Due to the complexity of the jeopardy analysis needed for most species, proposed and candidate species were evaluated in the same manner as listed species. Similarly, proposed critical habitat designations were considered in the same manner as designated critical habitat. We integrate and summarize our analysis and conference opinion together with listed species in the following subsections.

Some listed, proposed and candidate species and designated and proposed critical habitats were not considered in EPA's BE, and therefore, have EPA determinations listed as "Not in BE" or "NA" in the tables in the *Integration and Synthesis* sections below. These entities and critical habitats were included in this Opinion due to their status and occurrence in the action area at the time this Opinion was under development. Additionally, since the time the BE was submitted, there have been a number of species status changes, including reclassifications and delistings for listed species, and listing decisions for proposed and candidate species. As described in the *Concurrence* (Appendix A), we removed listed species that were in the BE from this consultation that have been delisted, along with proposed or candidate species for which listing was determined to be not warranted, and updated the status for other species, where appropriate. We will add proposed, listed, and candidate species and proposed and designated critical habitats that were not addressed in the 2021 BE in the final Opinion.

Summary of Status of the Species and Critical Habitat, Environmental Baseline, Cumulative Effects, and Effects of the Action

In the *Status of the Species* and *Critical Habitat*, *Environmental Baseline*, and *Cumulative Effects* sections of the Opinion, we established the effects of past and ongoing activities in the overall action area would maintain the existing degraded habitat conditions that are prevalent, although restoration activities and other conservation efforts may address some of the habitat conditions for some of the species, at least in part. We considered the status of the species and critical habitat through species-specific accounts (i.e., detailed in Appendix C). The *Environmental Baseline* and *Cumulative Effects* sections in the body of this Opinion were

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[21] All species and critical habitat included as proposed or candidate in EPA's BE are included in this Opinion or in the *Concurrence* (Appendix A) of the Opinion in this document, except species under review (e.g., candidate species) that were ultimately not listed, species that were delisted, and proposed critical habitats that were not designated (see Appendix D). For species that have been listed or critical habitat that has been designated since the final BE was submitted, the listing status has been updated in this Opinion.

broadly summarized and provided a generalized overview of the effects of previous and ongoing actions in the larger action area for the proposed action. Brief species-specific environmental baseline and cumulative effects considerations are included for species and habitat groups in their respective integration and syntheses summaries for each taxa group (Appendix C) and to varying degrees in the *Status of the Species* and *Critical Habitat* (Appendix B).

Numerous activities across the landscape have impacted the habitats and ecological communities on which listed species depend. A variety of land uses associated with human activities, such as agriculture and grazing, residential and commercial development, and forestry, have altered habitat over the long-term. Changes in land use such as development, land clearing, diking, and other activities have affected terrestrial and aquatic habitats. Water diversions and storage, replacement of pervious soils and surface with impervious materials, impacts to riparian buffers, loss of wetlands, stream channelization, and other activities have affected the water quality and quantity for many aquatic habitats. Discharges and runoff from many land uses also result in the degradation of water quality due to contaminants, such as excess nutrients, fertilizers, pesticides, and other chemicals. Numerous pesticides have been detected in various waterbodies throughout the country. In many habitats, pesticides and other pollutants are present in the environment at detectable levels, although these levels cannot generally be tied to specific application events or all of the sources that may be contributing to accumulative concentrations. Additionally, as noted in the *Effects of the Action* section, monitoring data from state and federal agencies described in the BE and other sources have indicated that multiple pesticides often co-occur in aquatic habitats located throughout the action area.

It is reasonable to assume that as some ecological communities are affected by extreme stresses or changing conditions over the short- or long-term future, pest pressures may increase. As discussed earlier with forests, activities such as timber harvest, grazing, fire suppression, road construction, and management practices, together with other influences (e.g., introduction of invasive species, climatic conditions) have resulted in increases in disease and pests. Although pests and disease have always been present in habitats, an increase in both native species viewed as pests, as well as introduced non-native pest species, may be of increasing concern in the future. Some pest species may impact various agricultural and non-agricultural actions related to the use categories, resulting in the use of various pesticides in the future that are not considered part of the action. We also recognize pesticides may, in some cases, also be used to benefit listed species or their critical habitats by reducing or eliminating competing, predatory or otherwise harmful species as part of a suite of activities to enhance or restore species habitats and support survival and recovery of the species.

Stressors that have influenced the environmental baseline and/or continue into the future as cumulative effects may often combine to result in an increased threat to sensitive species, where a single threat may have been less of a concern to a given species, its food base, habitat or other species (such as pollinators or hosts) on which it relies. The introduction of invasive species, together with other stressors, such as habitat impacts, pollution, harvest, and many other threats, is a major factor associated with species endangerment and loss of biodiversity across the action area. Combined with more frequent extreme weather events and other stressors on the landscape, including but not limited to increased frequency of drought or precipitation events, damaging storms, more or less frequent fire regimes, these stressors often exacerbate conditions that threaten a species' ability to persist. In coastal areas, sea level rise and ocean acidification are also expected to impact persistence of sensitive species that live in littoral, estuarine, or marine habitats.

In summary, we expect that numerous activities and resultant effects have occurred over the years and will continue into the future, and in many cases, will further degrade habitat conditions. We anticipate that, in some areas, restoration and recovery actions have and will continue to be undertaken to benefit listed resources to reduce impacts from these activities but are not necessarily anticipated to completely mitigate these impacts.

Recovery Considerations

We also generally considered threats and factors associated with the needs of listed species in order to support their potential for recovery in addition to their continued survival in our analysis. Recovery is achieved when the status of a listed species is improved to the point at which protection of the ESA is no longer needed based on the criteria in section 4(a)(1) of the ESA. When determining whether an action will likely jeopardize the continued existence of a listed species and/or destroy or adversely modify critical habitat, we evaluate whether the species will persist into the future and if it will have sufficient resilience to allow for the potential recovery from endangerment, in accordance with section 7(a)(2).

We reviewed the available recovery plans, 5-Year Reviews, and other Service information for each species to gather information about the status of the species, habitats areas and environmental elements essential for species' survival and recovery, as well as threats to the species and actions needed for recovery. The recovery goals, objectives, and reclassification and delisting criteria identified in recovery plans were reviewed to help us understand and assess threats to each species and also to understand the effects of the proposed action on the recovery potential for the species. Reclassification and delisting actions result from successful recovery efforts. Achieving recovery so that species can be delisted is the ultimate goal of the ESA. Information related to the species' recovery is included in the Status of the Species and Critical Habitat (Appendix B).

Approach to the Effects Analysis

Where the BE indicated likely effects to an individual of a listed species, we carried forward with a population level assessment. We assessed the following responses for each listed species, where applicable, by considering all lethal and sublethal effects observed in toxicity studies, including:

1. Mortality to portions of the population(s) of a listed species from direct, acute exposure from the use of methomyl according to registered labels;

2. Altered growth among portions of the population(s) (potential for decreased survival and/or reproduction) from the use of methomyl according to registered labels;

3. Reduced or impaired reproduction among portions of the population(s) from the use of methomyl according to registered labels, and

4. Indirect effects to species, including declines in availability of other organisms on which the species depends to complete its life history (e.g., prey/food of a listed species, host fish for mussel glochidia, pollinators/seed dispersers for plant species, symbiotic organisms) and impacts to suitability and/or quality of habitat on which the listed species depends.

As part of our assessment, we use qualitative rankings of high, medium, or low for a listed species' vulnerability, exposure, and toxicity. Each of these factors considers several pieces of information to inform the assignment of rankings for each species. To facilitate our analyses, we sort listed species based on the combination of vulnerability, exposure, and toxicity rankings, which allow us to prioritize species that may need more scrutiny based on common specific factors (e.g., species that may have high levels of exposure and have high toxicity, species that have high levels of exposure and are highly vulnerable).

For plants, before the qualitative rankings for vulnerability, exposure, and toxicity were determined for each species, we grouped species by reproductive strategy, as species that require insects to transport their pollen for successful reproduction are inherently more susceptible to the effects of an insecticide such as methomyl, than plants that do not use pollinators (e.g., ferns), those that may use pollinators but can also use other reproductive methods (e.g., self-fertilization, vegetative reproduction), and those that use wind or water for pollination. This upfront grouping allowed us to better understand the general level of concern for larger groups of plant species before determining individual species' rankings. A detailed description of these plant groupings, called Assessment Groups, are found in the *Toxicity* section of this Opinion.

Vulnerability

We considered several factors to summarize the current status and vulnerability of a listed species to additional stressors. This effort allows us to consider whether a species' current condition is moving toward recovery or further decline. In general, we expect the species' vulnerability to additional stressors to be higher if they are moving toward further decline than if they their condition is improving. We also identify which species are most (and least) susceptible to additional stressors in general based on information that could be surmised from species listing and recovery documents, or other sources as cited and considered in the *Status* section of this Opinion.

Our assessment of vulnerability focuses on six factors: (1) the species listing status and recent 5-Year Review recommendation (if available), (2) distribution, (3) number of populations, (4) species population trends, (5) if pesticides have been noted as a threat, and (6) impacts from activities associated with environmental baseline and cumulative effects. We obtained the information to create the vulnerability summary from the *Status of the Species* accounts (Appendix B), the overarching *Environmental Baseline* section of this Opinion, 5-Year Reviews, species recovery plans, species status assessments, and other sources containing the best available scientific information for the species.

Vulnerability factors related to distribution, number of populations, and species population trends are described further below.

Distribution

We considered the distribution of a species as a vulnerability factor with the general view that the smaller or more confined the range, the more susceptible the species may be to a disturbance or stochastic event. If a species was a narrow endemic, or otherwise limited to small, isolated, or fragmented habitats or habitat patches, we assigned a "high vulnerability" ranking to this factor. Where species were wide-ranging and/or able to easily recolonize new or existing habitats, we assigned a low vulnerability ranking to this factor. A "medium vulnerability" ranking was assigned to species that did not clearly fall into either the constrained or widespread categories.

Species that migrate can be considered to be inherently wide-ranging based on the extent of their ranges, especially for those that are long-distance migrants. However, parts of a species range that the species relies on seasonally, such as for breeding or overwintering, may be fragmented and constrained. The assignment of vulnerability rankings takes into consideration how vulnerable the species may be across its range as well as in seasonally used portions of its range within the U.S. In some cases, even though a "low vulnerability" ranking generally applies to wide-ranging species, a "high vulnerability" or "medium vulnerability" ranking for this factor may be assigned to migratory species to reflect more accurately how vulnerable the species may be in light of seasonal habitat requirements.

Numbers of Populations

For numbers of populations, we considered whether a species was limited to a single population, few populations, or many populations. The use of "few" versus "many" was necessarily subjective, as it is related to the species' distribution, redundancy, and resiliency to the effects of stochastic events that could result in extirpations of populations or subpopulations. Generally speaking, we consider "few" to be fewer than 10 populations, though for some species, we may consider "few" to be only two populations (or sub-populations, depending on the available species information). We assigned vulnerability ranking factors of: "high vulnerability" to species with a single population (or in some cases a single, small metapopulation, as appropriate); "medium vulnerability" to species with "few" populations, which allow for at least a limited level of redundancy to protect against stochastic events or localized extirpations; and "low vulnerability" to species with numerous populations, which may provide a greater level of redundancy.

Species Population Trends

For species population trends, we considered whether populations are declining, stable or increasing, based on the most recent information from listing rules, recovery plans, 5-Year Reviews and other Service sources for the species (e.g., Service species experts). We assigned vulnerability factors of "high vulnerability" to species with one or more declining populations; "medium vulnerability" to species with all stable populations where none are known to be increasing or decreasing, or unknown population trends, and "low vulnerability" for species with increasing population(s) trends. This factor indicates whether the species is moving towards extinction or recovery as part of the species status and baseline.

We acknowledge that for species population trend information, various life history considerations or the species status can complicate an observation of its trend. For example, a species that appears “stable” according to this ranking factor (i.e., neither increasing nor decreasing) may actually have a very small population size(s), which in some cases may not be sufficiently robust to maintain the population over the long term even though numbers may appear stable. While we recognize this is a potential shortcoming in this ranking factor, by evaluating this factor in combination with species distribution, population size, and the other considerations described above, we are less likely to assign the factor undue weight in determining the vulnerability of the species in such a scenario.

Pesticides Listed as a Threat

As we reviewed species information in listing rules and recovery documents to generate the vulnerability factors, we also noted when pesticides were identified as a threat to the species in these documents and included this as an indicator in our overall assessment of species’ vulnerability. However, pesticide threats were not always mentioned or consistently evaluated for a species in listing rules or recovery documents, and such an omission does not necessarily mean the species would not be vulnerable to that factor. As such, where pesticides were not noted as a threat in the listing or recovery documents, we treated this consideration as a neutral factor in our overall vulnerability ranking.

Vulnerability Ranking

We scored each of the six vulnerability components with high, medium, or low scores. We assigned a high vulnerability ranking to a species if all vulnerability components were scored as medium or high. We assigned a medium vulnerability ranking if a species’ scores were a mix of high, medium, and low (though exceptions were allowed for species that have a low status score or have an uplisting recommendation). We assigned a low vulnerability ranking to species with only low scores. Considerations regarding specific aspects of the species’ vulnerability or beyond what was included in the vulnerability ranking were applicable for some species depending on unique aspects of their life history. This information is reflected in the rationales for conclusion below.

Exposure

As described previously, we expect methomyl applications to occur on a site-specific basis for the duration of the proposed action. Our analyses include a quantification of areas where the pesticide can be applied according to the labels as currently written. We characterize the expected level of exposure using the extent of overlap between these methomyl use sites and the species’ range, past methomyl usage data, and any species-specific considerations such as life history information (e.g., habitat preferences, dispersal behavior), and existing protections or conservation actions.

Overlap

Overlap data refers to the extent that methomyl use sites (i.e., on-field areas) and adjacent areas likely to be exposed through off-site transport (i.e., off-field areas) occur within a listed species’ range and is reported by the EPA as a percentage for each relevant crop use type. We extend our off-field analysis to 90 meters from the edge of application sites as we determined this was the maximum distance at which effects are likely to occur to listed species. Our default approach is to assume that individuals of listed species are uniformly distributed throughout their range (see *Assumptions and Uncertainties for all species, Species Range Maps* section of this Opinion). We use this percent overlap to represent the proportion of individuals that may be exposed throughout the duration of the proposed action. We address species where available information indicate that a uniform distribution assumption is not appropriate on a case-by-case basis (see the *Additional Exposure Considerations* section below for more details).

We determine the total overlap between the species' range and the action area by summing the on- and off-field area overlaps with the species' range for each relevant use type (except for listed aquatic species, which we address below). We aggregate the overlaps across all non-highly redundant crop groups. Non-highly redundant crop groups refer to those crops that are not likely to be grown using the same fields (for example, crops that are not rotated out or replaced within the same field location such as other orchards and vegetables and groundfruit). The 'other orchards' use category consists of berries and fruit trees which need to be established over several years or growing seasons before they can bear fruit and thus are not rotated out after only a few growing seasons. In contrast, row crops (such as those in the 'vegetables and groundfruits' use category) may be rotated out over growing seasons for various reasons such as replenishing soil nutrients or availability or demand for certain crops. Redundancy in relation to use type refers to the fact that mapped use sites are not exclusive of one crop type over time. As such, for highly redundant crops such as corn and soybean, or citrus and other orchards, we use the higher overlap between the two redundant crop use sites in our total overlap calculations. Where certain crops are not labeled for methomyl use, they are not considered in the total. Wheat is only included in the total for species whose ranges occur in Washington, Oregon, or Idaho, which are the only states where methomyl is registered for use on wheat. Similarly, citrus is only included in the total for species whose ranges occur in California, Arizona, and Hawai'i, which are the only states where methomyl is registered for use on citrus orchards.

Based on the value of a listed species' total overlap, each species' overlap is given a score. Species with greater than 10% overlap are assigned a high overlap score, species with 5-10% overlap are assigned a medium overlap score, and species with less than 5% total overlap are assigned a low overlap score.

We modified our approach for characterizing overlap for the following groups of species: aquatic listed species, species occurring in Hawai'i, and species occurring in Pacific and Caribbean U.S. territories. We go into the specific overlap characterization process for these species below.

Aquatic species overlaps

We anticipate listed aquatic species will primarily be exposed to methomyl through contact with contaminated water in their habitats. We do not expect these species will occur on-field, and thus expect exposure will only result from off-field transport via spray drift or runoff into their aquatic habitats. Given that the ranges for listed aquatic species are generally delineated using the relevant U.S. Geologic Survey (USGS) Hydrologic Unit Code 12 (HUC 12) watersheds, we anticipate that all residues that leave use sites will be collected in the waterbodies within the species range where individuals occur regardless of how residues leave treated sites or where in the range they are deposited. As such, on-field overlap represents the total extent of agricultural activity within the species' ranges, and we do not extend overlap metrics off-field as this would not functionally change the expected exposures that listed aquatic species are likely to experience. Methomyl degrades quickly (i.e., within a few days) in aerobic aquatic habitats and as such is not likely to persist in water bodies for long periods of time, be transported long distances in surface waters, or occur in groundwater sources.

Hawaiian species overlap

Spatial distribution data for specific methomyl use sites are not available for the state of Hawaiʻi. We use available geospatial data from the Hawaiʻi Statewide GIS Program to calculate overlap metrics between listed species and critical habitats that occur in Hawaiʻi and agricultural areas. We are unable to separate the Hawaiʻi agricultural data into crops that are registered for methomyl use, and as such, expect overlap metrics are likely overestimated for listed species and critical habitats in Hawaiʻi. While aerial application of methomyl is an allowable application method in Hawaiʻi, available information from species and pesticide control experts in Hawaiʻi indicate that aerial application of pesticides is not expected to occur in Hawaiʻi. As such, we include additional data for off-field overlaps to 30 meters in addition to 90 meters as this may provide a more realistic estimate of the methomyl exposure footprint.

Pacific and Caribbean Island species overlap

Similar to listed species in Hawaiʻi, spatial data for specific methomyl use sites are not available for U.S. territories in the Pacific and Caribbean regions, including American Sāmoa, the Commonwealth of the Northern Mariana Islands, Guam, the U.S. Virgin Islands, and Puerto Rico. The EPA uses data from the National Oceanic and Atmospheric Administration's Coastal Change Analysis Program (C-CAP), which is a nationally standardized, raster-based inventory of land cover for the coastal areas of the U.S. Data are derived from the analysis of multiple dates of remotely sensed imagery. The EPA uses this data to characterize cultivated land use in the island territories. Similar to agricultural data in Hawaiʻi, we are not able to isolate areas where methomyl is registered for use and expect these metrics are likely to overestimate the extent of exposure to species.

Usage

Usage data refers to the maximum annual percent of a crop that has been treated with methomyl in the past. EPA uses past usage data, as summarized by the State Summary and Usage Matric (SUUM) in the BE, to calculate the percent of a species' range or critical habitat that is likely treated annually. Briefly, EPA calculates a percent crop treated at a state level, which they use to calculate the number of acres of a crop within a state that is treated within a year. Since the data do not indicate where within the state past usage has occurred, we conservatively assume that all treated acres of a crop occur within a listed species' range to determine the percent range treated annually. Similar to overlap, we assume that individuals of a listed species are uniformly distributed throughout their range, and that the percent range treated represents the likely proportion of individuals that will be exposed annually.

Similar to overlap, we determine the maximum percent of each species' range likely to be treated annually with methomyl by aggregating the percent range treated of all non-highly redundant crop groups. For most species, we do not expect all areas of a specific crop use site will be treated with methomyl each year. As such, total usage is typically smaller than overlap.

We score total usage based on the total percent area that is likely to be treated with methomyl annually. Species that data indicate will have a large portion of their range (>10%) treated with methomyl each year are assigned a high usage score. Species that will have a medium portion of their range (5-10%) treated with methomyl each year are assigned a medium usage score, and species that data indicate will have a low portion of their range (<5%) treated with methomyl each year are assigned a low usage score. In the sections below, we outline cases where available data results in a slightly different approach to assessing usage, including for species occurring entirely in the state of California, species occurring in Hawaii, and species occurring in the Pacific and Caribbean Island territories.

California Pesticide Use Report

The California Department of Pesticide Regulations' California Pesticide Use Report (CalPUR) provides spatially specific information regarding pesticide usage in the state of California. The state of California mandates pesticide usage reporting for all agricultural applicators and a subset of nonagricultural applicators. The EPA summarizes these data in terms of the percent of a species' range that has been reported to be treated with any pesticide, treated with any insecticide, and treated with methomyl over a 10-year period (2012-2021). The EPA also provides estimates of the average number of growers/applicators that report pesticide usage within the species' range in that same 10-year period, which we use as a surrogate metric for the potential variability in pesticide usage over time (e.g., a large number of growers reporting pesticide usage within a species' range indicates less variability in the total area treated each year as changes in pesticide usage of a few growers is not likely to affect the proportion of the range treated). Given that this state level data is spatially specific to the species' ranges and is this reporting is mandated by the state, we have a high confidence that these data more accurately represent likely exposure than other sources of usage data. As such, we replace the usage data provided in EPA's SUUM with CalPUR data for species and critical habitats that occur entirely within the state of California.

Pacific and Caribbean Island Usage Data

We omit this score for our analysis of listed species that occur in these areas. Methomyl specific usage data is not available for Caribbean or Pacific islands (including Hawaiʻi, Puerto Rico, the U.S. Virgin Islands, the Commonwealth of the Northern Mariana Islands, Guam, and America Sāmoa). As such, for most species that reside in these areas, we omit the usage score for our analysis of exposure and rely solely on the overlap with the action area. In general, we consider that the Census of Agriculture insecticide data provided by EPA for Puerto Rico and certain islands in Hawaiʻi confirms that insecticide usage occurs on these islands, with methomyl presumably among these insecticides. For Hawaiʻi, where appropriate (e.g., species with more spatially refined range maps), we use these data as an additional exposure modifier to estimate the extent that a species' range is likely to be treated with insecticides.

Additional Exposure Considerations

When information on a specific species indicates that exposure assumptions are not likely true (e.g., species are known to avoid agricultural areas, species that are only found in protected areas with no agricultural pesticide use), we qualitatively incorporate that information into our exposure rankings. Some examples of relevant information include knowledge of species' distribution on protected lands that are not likely to be treated with methomyl (e.g., national parks and national wildlife refuges), life history information that indicates a low likelihood of exposure (e.g., avoidance of agricultural areas), or additional sources of usage data, such as USDA's Census of Agriculture.

Life History Traits

Listed species often exhibit different and unique characteristics and behaviors that enable them to survive in their environments. For instance, species that occupy habitats that naturally accumulate lower levels of pesticides (e.g., aquatic habitats with high flow rates, terrestrial habitats located in remote areas far from agriculture) are not likely to experience high levels of exposure compared to species that live in areas surrounded by cultivated land or habitats that are likely to accumulate high levels of pesticides. Behavioral traits such as how and where individuals forage, and their tendency to use particular habitats can also be highly influential in their susceptibility to pesticide exposure. We qualitatively incorporate relevant life history traits that are expected to modify the level of expected exposure relative to our baseline assumptions where relevant species information is available.

U.S. Department of Agriculture's Census of Agriculture Data

The USDA's Census of Agriculture is reported at a county level and includes information on pesticide usage summarized by pesticide class (i.e., all insecticide usage). The EPA provides information in cases where there are low levels of general insecticide usage within the counties that a listed species' range occurs in. Given that these data are more spatially specific than methomyl-specific usage data available (with the exception of California, where data are available at a sub-county level) and covers all insecticides used (not just methomyl), we consider instances where the CoA reports low levels of usage for all insecticide within a species' range as strong evidence that methomyl usage is unlikely to exceed low levels of usage throughout the course of the action.

Exposure Ranking

We determine the overall exposure ranking by qualitatively considering both the total overlap and total usage (when available), as well as any additional exposure considerations that might modify the level of exposure likely to occur. When overlap and usage scores are the same, we assign the overall exposure ranking the same score (e.g., if both overlap and usage is high, the overall exposure ranking is high). In cases where overlap is high and usage is medium or when overlap is medium and usage is low, we use the overlap score as the overall exposure ranking to maintain conservative exposure assumptions, as usage is a subset of overlap and so the overlap score will always be greater than the usage score. In cases where overlap is high but usage is low, we anticipate a moderate portion of the range may be treated over the duration of the proposed action even if only a small portion of the range is treated in any given year (particularly if the areas treated occur in different locations each year). Thus, species with high overlap but low usage have an overall exposure ranking of medium. In cases where no usage data is available, in the absence of any additional exposure considerations for these species, our ranking is based on total overlap of methomyl use sites for species that occur in these areas. For all species, where there are additional exposure considerations, we adjust the overall exposure ranking to reflect this additional information, as appropriate.

Toxicity

We characterize the expected toxic effect to species based on the anticipated level of direct and indirect adverse effects to individuals. Our analysis of toxicity assumes individuals are exposed to methomyl at levels estimated by EPA's environmental exposure modeling and is focused on determining the level of adverse effect expected to occur once exposure has taken place. Direct effects are based on the anticipated level of mortality and sublethal effects (e.g., reduced growth) likely to occur in exposed individuals. Indirect effects are based on the impact a listed species is likely to experience when the organisms they rely on, such as those that act as food or habitat resources, are exposed to methomyl and experience adverse effects.

Direct adverse effects refer to adverse physiological impacts resulting from exposure to methomyl (whether it is through contact, inhalation, or ingestion). We use available toxicity data in surrogate species as reference points to estimate the level mortality or sublethal effects (e.g., growth or reproduction) to listed species. Given that mortality is the most adverse of direct effects to an individual of a species, we assign the most weight to direct adverse effects resulting in mortality when determining the toxicity ranking. Species that are likely to experience more than 10% mortality in exposed individuals are given a high direct effects score. Species that are likely to experience between 5-10% mortality of exposed individuals are given a medium direct effects score. Species that are likely to experience less than 5% mortality of exposed individuals and are not likely to experience sublethal effects are given a low direct effects score. Species that are likely to experience less than 5% mortality but are likely to experience sublethal impacts are given a medium direct effects score.

Indirect adverse effects refer to adverse impacts resulting from methomyl exposure of other organisms that an individual relies on (e.g., prey species that are exposed to methomyl). These impacts may result even if an individual is not exposed to any methomyl itself. We qualitatively score the expected level of indirect adverse effects a listed species will experience based on the dietary items the species relies on (or the effects to another species with which the listed species shares an obligate/symbiotic relationship with, e.g., mussel host fish for mussels, ant species for myrmecophilous butterflies, etc.). Species that are particularly reliant on species that are sensitive to methomyl at estimated environmental concentrations (e.g., insects) are assigned a high indirect effect score while species that use a variety of prey species with a range of sensitivities to methomyl and species that use food resources that are not affected by methomyl are assigned a medium or low indirect effects score, respectively.

To characterize the toxic effect of methomyl to listed species, we first select an appropriate reference point from the available toxicity data (e.g., lowest reported LD_{50} or LC_{50}, the HC_{05} from a species sensitivity distribution, lowest reported LOAEC for sublethal effects). We then compare estimated environmental concentrations that EPA provides for each species to the appropriate toxicity reference point to determine the general magnitude of adverse effect likely to occur. The reference data used to characterize the magnitude of direct and indirect adverse effects will vary by taxa and is dependent on the breadth and depth of information available. We summarize the different toxicity considerations taken for the different taxa groups in the sections below.

Toxicity Ranking

We determine the overall toxicity ranking for listed species by considering the expected levels of direct adverse effects (i.e., mortality and sublethal effects) and indirect effects (i.e., prey or habitat loss). Given the immediate impact of mortality on the continued existence of a species, we weight the mortality score highest. Similarly, we weight sublethal effects higher than indirect effects score. As such, species with high or medium level of mortality are given an overall toxicity ranking of high or medium, respectively. Species with a low level of mortality but are likely to experience sublethal effects are given an overall toxicity ranking of medium as we anticipate a mix of mortality and reduced fitness (via reduced growth or reproduction) are likely. Species with a low level of mortality and a low level of sublethal effects and a high or medium level of prey or habitat loss are given an overall toxicity ranking of high or medium, respectively. Species with low levels of mortality, low levels of sublethal effects, and low levels of indirect effects are given an overall toxicity ranking of low.

Invertebrates

We expect contact exposure is the primary route of exposure for listed invertebrate species. We separate our invertebrate analyses into arthropods and mollusks/snails as available toxicity data indicate that insects and crustaceans are highly sensitive to methomyl exposure while mollusks are not likely to experience adverse effects from methomyl at environmentally relevant exposure levels. We compare estimated environmental concentrations resulting from the aerially applied product to the lowest terrestrial arthropod reference LD_{50} to determine the level of mortality listed terrestrial arthropod species are likely to experience. We compare estimated environmental concentrations in water to the aquatic invertebrate HC_{05} to determine the level of mortality listed aquatic arthropod species are likely to experience. We compare estimated environmental concentrations in water to the lowest mollusk LC_{50} to determine the level of mortality listed snails and bivalves are likely to experience.

Given that arthropods are likely to experience high levels of mortality, we do not estimate levels of sublethal effects to listed arthropod species as we anticipate exposed individuals are likely to die before any sublethal effects can occur. In contrast, we do not further analyze the level of sublethal effects likely to occur to listed mollusk species as available toxicity data indicate no adverse effects to growth or reproduction are likely to occur at environmentally relevant exposures.

For listed invertebrate species that rely on other invertebrates (e.g., predatory insects, butterflies with symbiotic relationships with ants), we use the lowest insect LD_{50} or the aquatic invertebrate HC_{05} to estimate the loss of prey or symbionts in terrestrial and aquatic environments, respectively. For species that rely on vertebrates (e.g., listed bivalves that use fish host species for reproduction), we estimate the level of vertebrate mortality expected to occur at estimated environmental concentrations predicted to occur within the species' range. We do so by using a generic fish mortality dose-response curve that uses the HC_{05} from the fish mortality species sensitivity distribution EPA generated in the methomyl BE and a default slope of 4.5.

Terrestrial Vertebrates

We expect dietary exposure is the primary route of exposure for terrestrial vertebrates. The EPA provided dietary dosage estimates for listed terrestrial vertebrate species based on body weight, diet, metabolic rate, assimilation efficiency, mass of food consumed per day, and methomyl concentration on food for each dietary item a species consumes on-field and off-field. We used a dose-response curve with an LD_{50} (mass adjusted) and default slope of 4.5 to calculate the level of mortality expected to occur to a listed terrestrial vertebrate species consuming exclusively one dietary item. We compared estimated dietary dosages to the lowest NOAEC or LOAEC available for terrestrial vertebrates, as appropriate, to determine whether sublethal effects are likely to occur. While pesticide exposure can result in a broad scope of sublethal effects, our analysis is confined to the data submitted by registrants or available in the open literature, which for methomyl, was limited to growth and reproduction. Given that there is not sufficient toxicity data for amphibians or reptiles to create a separate analysis for these taxa, we used available bird toxicity data as a surrogate for terrestrial-phase amphibians and reptiles. We qualitatively adjusted the level of direct adverse effect based on available knowledge of whether a listed species is likely to exclusively consume one dietary item, whether individuals are likely to forage on-field or forage on prey that have recently foraged on-field, whether foraging is likely to occur soon after methomyl application, and other relevant life history features (e.g., foraging distance, home range size, specificity of diet).

We expect terrestrial vertebrates that consume other animals are likely to experience some indirect effects in the form of reduced availability of prey. For terrestrial vertebrate species that consume insect prey, we assumed that insects exposed on-field or within the 90-m offsite transport zone were likely to die. For terrestrial vertebrates that consume other terrestrial vertebrates, we estimated the level of indirect effect by generating toxicity analyses for generic prey species. We determined the level of mortality a generic small mammal (weighing 15 grams that consumes grass), a generic small bird (weighing 20 grams that consumes grass), a generic large mammal (weighing 1000 grams that consumes grass), and a generic large bird (weighing 1000 grams that consumes invertebrates) are likely to experience from feeding on use sites that have recently been treated with methomyl and from feeding off-field in areas exposed through runoff or spray drift. Similar to estimates of direct effects to terrestrial-phase amphibians and reptiles, we use estimates of toxicity to the generic small bird and generic large bird to represent the anticipated impact to amphibian and reptile prey. We qualitatively adjust the anticipated level of indirect effects based on any relevant life history traits, including information regarding prey preferences, ability to use multiple food resources, relevant foraging behavior, changes in diet across life stages, etc.

Aquatic Vertebrates

We expect contact with contaminated water is the primary route of exposure for aquatic vertebrates. The EPA provided estimated environmental concentrations (EECs) of methomyl for different types of aquatic habitats (e.g., low flow/shallow habitats, high flow/large volume habitats) within the each USGS hydrologic unit code level 2 (HUC2) watershed. We created a dose-response curve for a generic fish using the HC_{05} EPA reported in the methomyl BE as a generic LC_{50} and a default slope of 4.5 to calculate the percent mortality within the range of EECs predicted to occur in each listed fish's habitat. We compare EECs to the lowest reported NOAEC or LOAEC, as appropriate, to determine whether sublethal adverse effects are likely to occur. We qualitatively modified the expected level of direct and indirect effect based on any available information on general preference for specific types of habitats, if species use certain habitats at certain life stages or time of year, etc. Given that there is not sufficient data on amphibians to create a separate analysis for this taxon, we these lethal and sublethal endpoints for fish as a surrogate for aquatic-phase amphibians.

We use the aquatic invertebrate HC_{05} to estimate the level of invertebrate prey loss that is likely to occur at estimated environmental concentrations of methomyl. We use the same generic fish dose-response curve described above to estimate the level of fish prey loss that is likely to occur at environmental concentrations of methomyl to listed piscivorous aquatic vertebrates. We qualitatively adjust the likely level of prey loss based on available information on life history traits (such as known prey preference, ability to use multiple food resources, habitat use, changes in dietary requirements across life stages, etc.).

Plants

We initially assessed the plant taxa group, consisting of more than 900 individual species, based on 11 groupings categorized by taxonomy and reproductive strategy. As observed in available toxicity studies in plants, we anticipate no direct adverse effects to plant survival, growth, or reproduction are likely to occur at environmentally relevant concentrations of methomyl. As such, the focus of our analysis on listed plant species is on impacts to pollinators and seed dispersers, particularly insect pollinators and insect seed dispersers. It is well known that flowering plants that rely on pollination would likely be impacted by any reduction in the pollinators on which they depend (S. G. Potts, et al. 2010, Thomas, et al. 2004, Biesmeijer, et al. 2006). To estimate the level of indirect effects to listed plants, we compare predicted EECs to occur in the habitat of listed plant species to the lowest insect LD_{50}. We qualitatively adjust the level of indirect adverse effects to species based on available information regarding a listed plant species' relationship with pollinators (e.g., can a species be pollinated by non-insect vectors? Can a listed plant reproduce vegetatively? Is the species a pollinator generalist or specialist?).

While the majority of listed plants are flowering dicot plants with insect pollinators, many are monocots or use differing mechanisms other than seed development or pollination for propagation. We determined that the most effective approach to analyzing effects for all listed plants was to sort them into assessment groups based on their reproductive strategies due to the likelihood of methomyl exposure impacting this aspect of a given plant's life history. Plant Assessment Groups 1-3 are those listed species that are not flowering plants, and do not rely on a pollination mechanism for reproduction (lichens and ferns) or use wind for pollination (conifers;

the one listed cycad is an exception). The remaining Assessment Groups (4-11) are monocots and dicots that have varying pollination and propagation strategies, including a grouping where some of the information on these aspects of life history are unknown at this time.

In our assessment of adverse indirect effects to plants, we incorporated information regarding the reproductive method(s) a listed species uses (which are captured in our assessment groupings), what type of pollinators and seed dispersers are required (e.g., insect pollinators only, insect and bird pollination with abiotic seed dispersal, insect pollination but general biotic and abiotic seed dispersal, etc.), and whether the listed plant has a generalist, specialist, or obligate relationship with its pollinators and/or seed dispersers.

Plant Assessment Group 1 – Lichens

There are two listed species of lichen: the Florida perforate cladonia and the rock gnome lichen. Lichen are composite organisms formed from algae and fungi living in a mutualistic relationship. Lichens do not produce flowers or seeds, and therefore, they do not rely on pollinators or seed dispersers for reproduction. The primary means of reproduction of the lichens in this group is asexual, with colonies or organisms spreading clonally through vegetative reproduction. There is no available data on the toxicity of methomyl to lichen species. We assume lichens respond to methomyl similarly to vascular plants and are not likely to experience any direct adverse effects from methomyl exposure. In addition, since these species do not rely on pollinators or seed dispersers for reproduction, we do not anticipate there will be indirect adverse effects to individuals. EPA determined the proposed action would be “Not Likely to Adversely Affect” the lichen species, thus they can be found in our *Concurrence* (Appendix A), and we do not consider these species in the Opinion.

Plant Assessment Group 2 – Ferns and Fern Allies

Ferns and Fern Allies are a diverse group of seedless plants that do not have flowers and reproduce sexually via spores and dispersed by wind. Ferns and their allies can also reproduce asexually by means of vegetative reproduction in the form of bulblets or rhizomes. Available toxicity data indicate that plants are not likely to experience adverse effects to survival, growth, or reproduction with exposure to methomyl at environmentally relevant concentrations, suggesting no direct adverse effects to individuals are likely. Similarly, since these species do not rely on pollinators for reproduction, we do not anticipate there will be indirect adverse effects to individuals. EPA determined there would be “No Effect” to all ferns and fern allies, thus these species are found in our *Concurrence* (Appendix A), and we do not consider these plant species in the Opinion.

Plant Assessment Group 3 – Conifers and Cycads

Conifers and cycads are gymnosperms (i.e., vascular plants, usually trees or shrubs, that reproduce by means of an exposed seed, or ovule). Gymnosperms do not produce flowers and the vast majority disperse their pollen by wind. Available toxicity data indicate that plants are not likely to experience any adverse effects to survival, growth, or reproduction with exposure to methomyl at environmentally relevant concentrations, suggesting no direct adverse effects to individuals are likely. Similarly, since these species do not rely on biotic pollinators for reproduction (with the exception of the fading or cycad – see Appendix C), we do not anticipate there will be indirect adverse effects to individuals from loss of pollinators. However, some of these species use biotic vectors (such as birds or mammals) for seed dispersal and could experience very minimal adverse reproductive effects from decreased availability of these animal seed dispersal vectors. Given the minimal anticipated adverse effects to these species, EPA determined the proposed action was "Not Likely to Adversely Affect" the whitebark pine. This species is found in our *Concurrence* (Appendix A), and we do not consider this plant species in the Opinion. The remainder of the species in this Assessment Group had minimal anticipated adverse effects and are in Appendix C. Plant Assessment Groups 4 through 7 – Monocot angiosperms with varying pollination and propagation strategies.

Plant Assessment Groups 4-7 are monocot flowering plants. They are grouped based on their pollination vector and the ability of the plant to rely on alternate forms of propagation. Assessment group 4 includes those listed monocot plants that rely on abiotic pollination (wind, water), while Assessment Groups 5 and 6 include monocots with biotic pollination vectors that require outcrossing for successful reproduction or are capable of self-fertilization or asexual/clonal reproduction, respectively. Assessment group 7 includes monocot angiosperms where there was not enough information available to determine pollination vector (beyond it being biotic) or propagation strategy at this time. As discussed above, we assumed no direct impacts to monocot plants. Indirect effects were assessed based on pollination vector (insect, bird, mammal, abiotic, etc.) and ability to rely on alternative reproductive mechanisms to different pollinating species.

Plant Assessment Groups 8 through 11 – Dicot angiosperms with varying pollination and propagation strategies

Plant Assessment Groups 8-11 include dicot plants. Assessment group 8 is defined by those dicots with abiotic pollination agents, while Assessment Groups 9 and 10 include dicots with biotic pollination mechanisms that require outcrossing for successful reproduction or are capable of self-fertilization or asexual/clonal reproduction, respectively. Assessment group 11 includes dicot angiosperms where there was not enough information available to determine pollination vector (beyond it being biotic) or propagation strategy at this time. We assessed these groups based on direct impacts to dicot plants from the toxicity data discussed above and indirect effects to different pollination vectors.

As methomyl has no direct effects on monocot or dicot flowering plants, in our Integration and Synthesis assessment appendices for plants, we combined monocots and dicots in groupings. For organizational purposes, we also divided these plant species by location, either CONUS or outside of CONUS (i.e., non-lower 48 or NL48 including the Pacific and Caribbean Island states and U.S. territories). As such, Plant Assessment Groups 5 and 9, 6 and 10, and 7 and 11 are placed together, and there are two sets of these groupings, one for CONUS and the other for NL48 plant species.

Rationales and Conclusions

Once the overall categories for each factor are determined for each species using the Integration and Synthesis Worksheet, we continue the jeopardy analysis by considering the combination of the overall vulnerability, exposure, and toxicity rankings described above, which include any additional information relevant to the consequences of the action that may reduce the species reproduction, numbers, and distribution.

Species Groupings

To facilitate our analyses, we group species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations are likely to have a similar risk profile and jeopardy determination. In cases where a combination of rankings provides a clear narrative for a determination that the proposed action is not likely to jeopardize the continued existence of a listed species, we provide a group rationale that outlines how the combination of vulnerability, exposure, and toxicity rankings results in this conclusion for all relevant species. Within these grouped rationales, we add additional information, when relevant, to support our conclusions. We review each grouped rationale to ensure that all vulnerability, exposure, and toxicity assumptions made are applicable for each species within the group and are expected to result in a similar determination for each species. We remove any species from the grouped rationales when our assumptions are not applicable, require additional information to make a determination, or otherwise present unique circumstances that warrant additional discussion. For these species, we provide individual *Integration and Synthesis* summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination.

In general, species with low exposure and low toxicity rankings are at a low risk of jeopardy, regardless of their vulnerability ranking, as the level of adverse effects will be limited in scope and magnitude. We group these species together as we have a low concern about adverse effects. Species with low exposure are often also at low risk of jeopardy given that we anticipate only small number of individuals are likely to be exposed. We group these species together based on the metric we use to conclude they have low exposure (e.g., overlap with the action area, low usage within the range of the species). However, species with low exposure that are especially vulnerable to extinction (e.g., severely small population numbers, pesticides listed as a major threat to the species) are removed from these groups as applicable, as even low levels of exposure and adverse effects can have significant consequences for highly vulnerable species. For all other species (i.e., species with medium or high exposure, and medium or higher toxicity), our preliminary exposure and toxicity rankings indicate that the proposed action may result in moderate to high adverse effects. As such, we discuss each species in more detail in individual Integration and Synthesis summaries. Where applicable, we modify initial exposure and toxicity rankings due to additional information regarding exposure and effects for individual species.

Effects of the Action on Animals

In the Integration and Synthesis summaries (Appendix C), we evaluate the results of exposure to methomyl for each taxa group (as described in the *Effects of the Action* section of this Opinion).

Generally speaking, we anticipate relatively high levels of mortality for both aquatic and terrestrial invertebrates where exposure occurs. For other taxa groups, we anticipate variable levels of mortality, and indirect effects based on their life history, prey base, insect pollinators (and in some cases, seed dispersers), or host fish, and other considerations following exposure to methomyl. We summarize these results and related conclusion rationales for the species in the sections below.

For each animal species, we considered the information described above and developed a rationale for the conclusion. Within each taxa group, we documented our determinations for each endangered and threatened species and critical habitat. Proposed species and critical habitat, as well as candidate species, are included in the taxa group tables, and determinations for each are provided as part of our conference biological opinion. Our analyses for species are provided in the sub-appendices of Appendix C and for critical habitats in Appendix D. Each taxa group and associated assumptions and narratives are included in the sections below. Where rationales for conclusions could be written broadly enough to apply to multiple species within a taxa or geographic group (e.g., snails, mussels), we streamlined reporting to the different exposure groupings as discussed earlier, for clarity and to avoid redundancy. Conclusions for all species addressed in this Opinion are in Table 1 below.

Table 28. Listed, proposed, and candidate species addressed in this Opinion.[22]

Table 28 Methomyl
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Amphibians

This taxa group includes species from the orders Anura and Caudata, including frogs, salamanders, and toads. All amphibians are ectothermic and have skin that is permeable to air and water. Frogs and toads share many similar life history characteristics.

Frogs (family Ranidae) and toads (family Bufonidae) generally have both an aquatic and terrestrial phase; although adults of some species may spend more time on land (e.g., Yosemite toad, California red-legged frog), others may spend most of their time in their aquatic environment (e.g., mountain yellow-legged frog), only moving onto land to occasionally forage along the water's edge. Both frog and toad families lay eggs in an aquatic environment, which develop into tadpoles and eventually metamorphose into adults. Metamorphosis may occur within a single breeding season or over one to three breeding seasons depending on environmental conditions. One family of frogs (Eleutherodactylidae) includes species that lay eggs that hatch directly into small frogs (e.g., Guajón) and a species that is ovoviviparous, giving birth to live young (golden coquí).

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[22] For calls and conclusions: LAA = "May affect, likely to adversely affect;" NLAA = "May affect, not likely to adversely affect;" NJ = "No Jeopardy;" NDAM = "No destruction or adverse modification;" NA = Not Applicable (e.g., critical habitat has not been designated for a species).

Salamanders exhibit a diverse array of life history characteristics. For instance, the family Plethodontidae (lungless salamanders) includes fully terrestrial species (e.g., Jemez Mountains salamander) which breathe entirely through their skin, lay eggs in a underground burrow, and have hatchlings that resemble small adults compared to fully aquatic species (e.g., Georgetown salamanders) that retain their gills throughout adulthood. Mole salamanders (family Ambystomatidae) have adults that are fully terrestrial, have fully developed lungs, and spend most of their time in underground burrows, but return to their natal breeding habitat to lay eggs which become tadpoles with gills until undergoing metamorphosis. The vast majority of amphibians that have an aquatic phase tend to spawn large numbers of eggs with limited or no parental care after laying (e.g., Oregon spotted frog). Terrestrial salamanders spawn far fewer eggs (typically under 20) in which the parent often guards the eggs until hatching (e.g., Shenandoah salamander). Both aquatic and terrestrial amphibians typically remain within or very close to their natal habitat (e.g., Texas blind salamander, Shenandoah salamander), while amphibians that have both an aquatic and terrestrial phase may remain close to their natal breeding habitat (e.g., Wyoming toad) or may travel several miles in search of suitable upland habitat or even new breeding habitats (e.g., California red-legged frog, Houston toad).

Effects to the Amphibian Species

Because some amphibians can have both a terrestrial and aquatic phase, we considered the risk of adverse effects in both habitats in our analysis for these species (e.g., California tiger salamander, Houston toad, mountain yellow-legged frog, etc.).

Use areas for methomyl overlap with and occur adjacent to habitats used within the ranges of all the listed amphibian species in this consultation. Exposure to this pesticide can result in mortality from exposure to concentrations in water, mortality due to the consumption of contaminated food resources, and the loss of important food resources that can lead to starvation, reproductive failure, site abandonment, or other detrimental effects. The effects can vary greatly by species depending on the degree of overlap between pesticide uses and the species range, the species' preferred habitats, and the diet of the species considering how their food resources may be affected. Amphibian tadpoles generally feed on algae and detritus, while adults eat aquatic and terrestrial invertebrates, and in the case of larger frogs and toads, small terrestrial vertebrates. These food resources are susceptible to contamination by pesticides as direct adverse effects that can in turn reduce the food supply available to amphibians. The anticipated exposures and pesticide effects on amphibians and their food resources, as well as the status of the species and factors related to their vulnerabilities, were considered when evaluating the effects of the proposed action on each amphibian species.

Terrestrial-phase Amphibians

Few toxicity studies are available for terrestrial amphibians exposed to methomyl. The available toxicity data and thresholds for birds are used as a surrogate for terrestrial amphibians. There is notable uncertainty in using birds as surrogates for amphibianss as it is assumed that they will have similar responses to methomyl. As discussed in the *General Effects*, dietary exposure was determined to be primary driver of effects for terrestrial vertebrates for methomyl, and thus we focus our discussion on that. For terrestrial-phase amphibians that forage in or adjacent to pesticide use sites, risk of mortality was dependent on the diet and body weight of individuals, as well as whether they could be expected to forage on-field or forage off-field and thus experience exposure in this manner. We expect off-field effects to be low for all amphibians, while we expect mortality amphibians that forage on-field, particularly those that consume soil invertebrates (e.g., Santa Cruz long-toed salamander, Puerto Rican crested toad). We expect species that forage on aquatic dietary items (e.g., benthic invertebrates, fish; Chiricahua leopard frog, Sonora tiger salamander) to experience the least mortality. This is not unexpected as, in many cases, terrestrial prey are expected to have higher concentrations of methomyl due to more direct exposure (e.g., terrestrial invertebrates may have pesticide residues directly deposited on the surface of their bodies, as opposed to aquatic vertebrates or invertebrates that accumulate pesticide residues that are diluted in water). Additionally, larger species generally have less risk than smaller species eating the same dietary items. As most amphibians have a similar diet (e.g., terrestrial invertebrates), body weight was the largest influence due to conversion for dose-based endpoints.

There were a number of species for which we predicted very little mortality due to low overlap, low usage, life history traits that preclude them from exposure, or a combination of these (Yosemite toad and California red-legged frog in high altitude waterbodies in the Sierra Nevadas on national forests, Cheat Mountains salamander which spends most of its life cycle in underground burrows within the Monongahela National Forest, and the Red Hills and Sonora tiger salamanders which also occupy burrows for most of their lifecycle, which largely precludes them from methomyl exposure). Based on available toxicity data, we do not expect effects to growth or reproduction for individuals that may be exposed at concentrations below the threshold at which we expect mortality.

We anticipate loss of forage and prey resources for terrestrial-phase amphibians that consume most animal-based dietary items, influenced by the likelihood of a species to enter a use site, where we expect higher levels of mortality to prey species, as discussed above. We do not anticipate any impacts to plants from methomyl, thus we did not anticipate any impacts to terrestrial amphibians from loss of plants as dietary items.

Aquatic and aquatic-phase amphibians

Few toxicity studies are available for aquatic amphibians exposed to methomyl. The available toxicity data and thresholds for fish are used as a surrogate for aquatic amphibians. There is notable uncertainty in using fish as surrogates for amphibianss as it is assumed that they will have similar responses to methomyl.

Risks posed by labeled uses of methomyl across the range of aquatic amphibians were most influenced by the amount of agricultural activity in the range (overlap), the amount of methomyl usage with the range, and the waterbodies inhabited by the species (based on volume and/or flow). Most amphibians with aquatic phases inhabit small streams and small ponds, particularly during early life stages. Though some species occupy larger rivers and streams (e.g., Black warrior (Sipsey Fork) waterdog, Ozark hellbender). Methomyl use near low flow or small static habitats can pose high risk of mortality and the percent of exposed individuals predicted to die from estimated environmental concentrations in these waterbodies ranged from 0.2 to 99%, depending on the region, for these species. EECs in smaller size or flow waterbodies frequently were estimated to cause high direct mortality and high indirect effects on prey.

In most cases where exposures were low enough such that direct adverse effects were not anticipated, there was still risk from indirect effects, because of high mortality to aquatic invertebrate prey (e.g., California tiger salamander - Sonoma County, Santa Barbara, and Central California DPSs).

As discussed in the *Approach to the Effects Analysis* section, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We remove any species from the grouped rationales when our assumptions are not applicable, require additional information to make a determination, or otherwise present unique circumstances that warrant additional discussion. For these species, we provide individual Integration and Synthesis summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination.

The amphibian species included in this Opinion, and our conclusions for each, are presented in Table 28. In addition to the species vulnerability assessments and summarized Environmental Baseline and Cumulative Effects information relevant to the analysis, we further discuss the effects of the action, and our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon in Appendix C. In this appendix, we present our grouped and individual integration and synthesis summaries all amphibians considered in this Opinion.

Bivalves (Mussels)

The mussel species in this taxa group includes individuals from the families Margaritiferidae and Unionidae. Of the approximately 90 species in this taxa, only the Alabama pearlshell and the spectaclecase occur in the family Margaritiferidae; the rest occur in the family Unionidae. In general, threats to bivalves are associated with habitat alteration and degradation (e.g., sedimentation, river channelization, river impoundment, drought, nutrient enrichment, chemical contamination) and introductions of non-native species (Master 1993, Neves, Bogan, et al. 1997, Neves 1999, Havlik and Marking 1987, Schloesser and Nalepa 1995, Schloesser, Nalepa and Mackie 1996, Stewart and Swinford 1995). Impacts from past and ongoing threats have left many species in these taxa with one or few remaining populations that are typically fragmented and isolated from one another. Population status is generally characterized as declining or unknown.

All mussel species in this analysis use a fish host to complete their reproduction cycle. Both Unionidae and Margaritiferidae mussels vary in their host specificity. Some mussel species can use a variety of fish species as hosts, but they are usually limited to one or two families of fishes. A small number of mussels appear to be limited to a single fish host (obligate host); for example, the scaleshell appears to utilize the freshwater drum (*Aplodinotus grunniens*) exclusively as a host for its larvae. The reproductive life cycle involving the fish host begins when glochidia (i.e., parasitic larvae) are released from the female mussel and attach to the appropriate fish host and the fish host's epithelial cells form a cyst around the glochidia. The glochidia have a parasitic relationship with the host, deriving all their nutrients from the host for several weeks or months as they transform into juvenile mussels. After transformation, the juvenile mussel drops from the host fish and buries into the sediment.

Effects to the Mussel Species

As described in the *Approach* section above, we used exposure and toxicity data, in combination with relevant life history information, to assess all mussels for effects to the proposed action. For all uses of methomyl, we do not anticipate direct effects (mortality or sublethal effects) to the mussels themselves. However, we do anticipate use of methomyl will cause mortality to many individuals of host fish directly exposed to methomyl either through exposure to runoff or spray drift from applications. This exposure may vary depending on waterbody type as described previously in the *General Effects* section. For example, for host fish with some or all life stages in small flowing or static waterbodies (e.g., some darters, sculpins, mosquito fish, stonerollers, some minnow), mortality effects are generally likely to be higher than those in larger water bodies, like larger rivers or lakes (e.g., large and smallmouth bass, logperch, catfish, and bullhead). We anticipate variable degrees of effects to host fish, although most uses, particularly near smaller waterbodies, are likely to result in high levels of mortality where exposure occurs. Because methomyl has such high acute lethal toxicity, mortality is the predominant effect driving risk.

For host fish species that prey on invertebrates or fish, we anticipate contamination of or reduction in their forage base as well, reducing the suitability and availability of food items. Reduced food availability to the host fish could result in substantial effects on individual host fish or their populations, particularly in habitats where food resources may already be relatively scarce. Where localized effects to reductions in zooplankton prey occur from applications of methomyl, we anticipate these to be relatively short-term, whereas additional food resources from upstream sources would quickly recolonize or host fish would seek out other areas of available prey, where sufficient habitat is present to do so. In static water bodies, such has larger lakes, we anticipate localized effects to reductions in zooplankton prey would also occur from applications of methomyl. However, these invertebrate prey resources are also likely to be replenished over a short period of time from within or close to the habitat. However, where unaffected areas are limited due to fragmented habitat, and during the time in which prey resources have adequately re-established to provide a sufficient prey base, we anticipate reduced ability of host fish to forage and mortality or reduced body condition for these fish. Such effects would result in lower survival and reproduction of affected host fish. Mussels generally consume phytoplankton and detritus, which is not anticipated to be impacted by methomyl applications.

As we considered the effects of the proposed action on the species, we recognized the pesticide would not be used on every application/use area, and would not be used at the same time, during the same year, or at the maximum labeled uses for every application. It is thus reasonable to assume some of these applications will occur on multiple sites on consecutive days or weeks or during the same year. Where individual host fish are lost, or a large proportion of a population(s) of host fish are lost, individual mussels would eventually be lost to natural mortality over time without the ability to successfully breed. Since many adult mussel numbers are already low in many populations (e.g., orangefoot pimpleback (pearlymussels), rabbitsfoot, Suwannee moccasinshell, tapered pigtoe, and Tar River spinymussel), and their habitats are isolated and fragmented, currently populated areas may be lost and not recolonized in the absence of measures to reduce exposure and effects.

Exposure varied among the species based on the aquatic habitats in which they are found from low to high. We expect high adverse effects to fish hosts as estimated environmental concentrations are sufficiently high to cause mortality in these species. The loss of the fish host predicted for listed mussel species is particularly relevant as the continued survival of any listed mussel species is directly reliant on a fish host for glochidia to attach and derive nutrients as it grows and matures. For many species, if the mussel were able to have their glochidia attach to multiple species of fish host (e.g., pink mucket, shiny pigtoe, Alabama moccasinshell, and many others) or if they had a small group of very common fish hosts (e.g., Higgin's eye pearlymussel, Alabama lampmussel, pink mucket, fat pocketbook), adverse effects to the mussel species were generally less than that for species where the fish host were a few very specific species of fish or unknown fish hosts (i.e., Ochlockonee moccasinshell, Chipola slabshell, Altamaha spinymussel). In particular, adverse effects were most severe if the mussel and the fish host occupied smaller flowing or smaller sized water bodies such as small streams or ponds (e.g., white cat's paw (pearlymussel)).

As discussed in the *Approach to the Effects Analysis* section, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We remove any species from the grouped rationales when our assumptions are not applicable, require additional information to make a determination, or otherwise present unique circumstances that warrant additional discussion. For these species, we provide individual Integration and Synthesis summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination.

The bivalve species included in this Opinion, and our conclusions for each are presented in the *Integration and Synthesis* summaries for grouped bivalves and species with individual summaries can be found in Appendix C. The bivalve species included in this Opinion, and our conclusions for each, are presented in Table 28. In addition to the species vulnerability assessments and summarized Environmental Baseline and Cumulative Effects information relevant to the analysis, we further discuss the effects of the action, and our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon in Appendix C. In this appendix, we present our grouped and individual integration and synthesis summaries all bivalves considered in this Opinion.

Birds

Birds are a diverse group in the class Aves, which is divided into 23 taxonomic orders based on the similarity of their characteristics: ducks, geese, and swans (Anseriformes); grouse, quail, and allies (Galliformes); grebes (Podicipediformes); pigeons and doves (Columbiformes); cuckoos (Cuculiformes); nightjars (Caprimulgiformes); swifts and hummingbirds (Apodiformes); cranes and rails (Gruiformes); plovers, sandpipers, and allies (Charadriiformes); loons (Gaviiformes); tubenoses (Procellariiformes); storks (Ciconiiformes); frigatebirds, boobies, cormorants, darters, and allies (Suliformes); pelicans, herons, ibises, and allies (Pelecaniformes); New World vultures (Cathartiformes); hawks, kites, eagles, and allies (Accipitriformes); owls (Strigiformes); trogons and quetzals (Trogoniformes); kingfishers and allies (Coraciiformes); woodpeckers (Piciformes); caracaras and falcons (Falconiformes); parrots (Psittaciformes); and perching birds (Passeriformes).

Birds are ubiquitous throughout the landscape, as they can be found using virtually every type of habitat and land use across the full spectrum of terrestrial and aquatic environments. Each bird species generally occurs within certain habitat types and specific geographical areas, although ranges for many bird species are expansive, especially for species that migrate. Resident species stay in the same area year-round, although they may make seasonal movements between local habitat areas. Migratory birds tend to have complex and extensive habitat needs, requiring networks of appropriate habitats in key locations across large geographical areas that include most available land uses. They require suitable habitats in different places for breeding and overwintering, as well as flyways and stopover sites for travelling, resting, and refueling during migration. Effects of reductions in habitat quantity and quality, the primary causes of negative population trends for many species, are often exacerbated by the direct loss of bird life from environmental hazards. Clean air, clean water, and abundant, diverse, and healthy habitats are essential for listed bird species to survive and recover.

Effects to the Bird Species

As described in the *Approach* section above, we used exposure and toxicity data, in combination with relevant life history information, to assess all birds for effects to the proposed action. In addition to the species vulnerability assessments and summarized Environmental Baseline and Cumulative Effects information relevant to the analysis, we discuss our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon. More detail on the approach for the subsets of species and usage categories is provided in the birds *Integration and Synthesis* summary (Appendix C).

Exposure varied among the species based on the habitats in which they forage, breed, and shelter from low to high. For all use types, we anticipate birds exposed to methomyl may die depending on the species and dosage. Sublethal effects, such as reduced growth or reproduction, are possible with methomyl exposure, but we expect mortality to occur before sublethal effects are likely to occur for birds exposed at concentrations estimated from dietary exposure. For birds that rely on plant foods (e.g., grasses, leaves, fruits) like masked bobwhite (quail) and Puerto Rican plain pigeon, we do not expect individuals to experience indirect effects from reductions in food or habitat resources from the proposed action. For birds that rely on arthropods or other invertebrates (e.g., light-footed Ridgway's rail, southwestern willow flycatcher, golden-cheeked warbler, Least Bell's vireo, and piping plover), we expect adverse indirect effects from reductions in prey resources. For birds that rely on other vertebrates for food (e.g., Puerto Rican sharp-shinned hawk, northern aplomado falcon, and wood stork), they may experience a wide range of adverse indirect effects depending on the prey items and whether the prey items are exposed to methomyl on-field or off-field. We expect birds that forage for invertebrates on-field to experience the highest levels of mortality and birds that forage on aquatic species will experience the lowest levels of mortality from methomyl exposure.

We recognized methomyl would not be used on every application/use area, and would not be used at the same time, during the same year, or at the maximum labeled uses for every application. It is thus reasonable to assume some applications will occur on multiple sites on consecutive days or weeks or during the same year. Some birds occur in a single population (e.g., Yuma Ridgway's rail, Mississippi sandhill crane, Mariana crow, and Audubon's crested caracara) and their habitats are isolated and fragmented (e.g., whooping crane, Mississippi sandhill crane, Puerto Rican nightjar, Audubon's crested caracara, and eastern black rail). Currently populated areas may be lost and not recolonized in the absence of measures to reduce exposure and effects to several listed birds.

As discussed in the *Approach to the Effects Analysis* section, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We remove any species from the grouped rationales when our assumptions are not applicable, require additional information to make a determination, or otherwise present unique circumstances that warrant additional discussion. For these species, we provide individual Integration and Synthesis summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination. For birds, we included species that have been proposed for delisting (i.e., ‘ō‘ū (honeycreeper), Eskimo curlew, wood stork) in these groups and provided rationales for our determinations.

The bird species included in this Opinion, and our conclusions for each are presented in Table 28. In addition to the species vulnerability assessments and summarized Environmental Baseline and Cumulative Effects information relevant to the analysis, we further discuss the effects of the action, and our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon in Appendix C.

Crustaceans

The crustaceans taxa group includes the following orders: Amphipoda (amphipods); Anostraca (fairy shrimp), Decapoda (shrimp, crayfish), Isopoda (isopods), and Notostraca (fairy shrimp, tadpole shrimp). Most are aquatic and dwell in streams, vernal pools, or subterranean habitats. Several partially terrestrial species live in ephemeral habitats (i.e., vernal pools), and are adapted to survive periodic dry conditions (e.g., cyst phase of fairy shrimp and tadpole shrimp).

Effects to the Crustacean Species

As described in the *Approach* section above, we used exposure and toxicity data, in combination with relevant life history information, to assess all crustacean for effects to the proposed action. We anticipate all crustacean species will be directly affected from exposure through concentrations in water or through dietary exposure. As we do not generally expect survivors where individuals are exposed, sublethal effects are not anticipated for crustaceans. For species in streams, wetlands, and non-subterraneous aquatic habitats, we anticipate that drift or runoff from nearby applications may reach the species habitat as described in the *General Effects* section. Effects to invertebrate prey or invertebrate constituents of detritus in the forage base were not considered in the analysis, although it is reasonable to assume additional indirect effects may occur to these species via temporary reductions in prey resources after applications.

We anticipate that many of the crustaceans considered in this Opinion will experience high levels of mortality (up to 100% of exposed individuals) from methomyl uses where exposure occurs. For many narrow endemics, any mortality could result in species-level effects due to isolation and low population numbers. High risk to crustaceans was observed for all species of listed crustacean but overlap and usage varied from (0-74%) and high toxicity was anticipated based on toxicity data and listed crustaceans mostly residing in low flow and smaller static water bodies which tend to concentrate the pesticide more than larger waters or higher flowing waters.

Indirect effects were not analyzed for crustaceans but assumed that most indirect effects items considered for an aquatic invertebrate that involve dietary items such as other aquatic invertebrates as dietary items, would also experience similar mortality. Other aquatic dietary items such as detritus, algae or phytoplankton were not considered in indirect effects for crustaceans as these dietary items would not have any adverse effects or reductions in avaialblity to the listed crustacean from methomyl exposure.

Generally, crustaceans are considered to have very limited ranges and are endemic to specific habitat locales (e.g., vernal pools, certain cave species, freshwater springs) and thus were found to be more at risk from methomyl exposure. Therefore, the combined high hazard (i.e., toxicity) of methomyl to these taxa and high exposure of methomyl to listed crustaceans resulted in a high risk of mortality to these species. For cave-dwelling crustaceans (i.e., cave crayfish, Madison cave isopod, Peck's cave amphipod, Alabama cave shrimp, Kentucky cave shrimp, Illinois cave amphipod, Kaua'i cave amphipod), we do not anticipate that direct application or drift are likely pathways of exposure. We do not anticipate cave species will be exposed to methomyl based on its environmental fate and physical chemistry properties. Methomyl is not persistent and will not be available to reach cave habitats when recharge occurs to these habitats where these species reside and thus will not impact these species from surface waters entering karst systems. For more discussion on this, see section *Exposure Pathways for Cave Species.*

In addition, methomyl exposure within the range of many of these species was generally low through a combination of the analysis of the overlap and usage and thus adverse effects to this listed taxa group were often found to be low, even to species with high vulnerability (e.g., Hay's spring amphipod, Shasta crayfish, Guyandotte River crayfish, Conservancy fairy shrimp).

As discussed in the *Approach to the Effects Analysis* section, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We remove any species from the grouped rationales when our assumptions are not applicable, require additional information to make a determination, or otherwise present unique circumstances that warrant additional discussion. For these species, we provide individual Integration and Synthesis summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination.

The crustacean species included in this Opinion, and our conclusions for each, are presented in Table 28. In addition to the species vulnerability assessments and summarized *Environmental Baseline* and *Cumulative Effects* information relevant to the analysis, we further discuss the effects of the action, and our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon in Appendix C. In this appendix, we present our grouped and individual integration and synthesis summaries for all crustaceans considered in this Opinion.

Fish

The fish species in this taxa group include a wide variety of families: sturgeon (Acipenseridae), cavefish (Amblyopsidae), a silverside (Atherinidae), suckers (Catostomidae), sunfish (Centrarchidae), sculpins (Cottidae), dace, minnows, and other cyprinids (Cyprinidae), goby (Gobidae), madtoms (Ictaluridae), smelt (Osmeridae), darters and logperch (Percidae), mosquitofish and topminnows (Poeciliidae), and salmonids (Salmonidae). Most are freshwater species, with a few species of sturgeon, salmonids, and smelt using freshwater, estuarine, and/or marine waters at different stages in their life cycles.

Effects to the Fish Species

As described in the *Approach* section above, we used exposure and toxicity data, in combination with relevant life history information, to assess all fish for effects to the proposed action. For all uses of methomyl, we anticipate mortality will occur to exposed individuals of most species, although this varies by waterbody type as described previously in the *Effects of the Action* section. We anticipate variable degrees of effects to fish, although most listed fish species spend part or all of their life cycle in small streams with low flow, and nearly a third live in small ponds or small lakes. Methomyl use near these habitats can pose high risk of mortality. For species with some or all life stages in small flowing or low volume static waterbodies (e.g., Apache trout, Kendall Warm Springs dace, Okaloosa darter, watercress darter, Sonora chub, Hiko White River springfish, Barrens topminnow, and others), mortality effects are generally likely to be higher than those species in larger static or flowing water bodies, like larger lakes and ponds or larger rivers and streams (e.g., snail darter, spotfin chub, leopard darter, Roanoke logperch, pygmy sculpin, Waccamaw silverside, Alabama sturgeon, Rio Grande silvery minnow, and others). Because methomyl has acute lethal toxicity to fish, we expect mortality to be the predominant effect. For species that prey on invertebrates or fish, we anticipate contamination of or reduction in their forage base as well, reducing the suitability and availability of food items. Reduced food availability could result in substantial effects on individuals and populations of a species, particularly in habitats where food resources may already be relatively scarce. However, based on methomyl use overlap with the species range, and consideration of usage data (as described in the *Effects of the Action* section), in many cases, the likelihood of exposure is very low.

For species that inhabit springs, streams, vernal pools, and other wetlands (e.g., Topeka shiner, Yaqui chub, Clover Valley speckled dace, Lost River sucker, bonytail chub, Ash Meadows speckled dace, Warm Springs pupfish, and others), we anticipate exposure from methomyl drift and runoff from treated fields. The Alabama cave fish, Ozark cave fish, and Grotto sculpin live in caves or other subterranean environments. As with other cave species described in previous sections, we do not expect that methomyl is expected to be present in concentrations that enter caves, and thus effects to individuals of these species or their prey are not expected in caves. (see section *Exposure Pathways for Cave Species*). However, as the grotto sculpin is expected to leave the cave habitat, we anticipate that exposure to this species in waters outside the cave will result in adverse effects.

As discussed in the *Approach to the Effects Analysis* section, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We remove any species from the grouped rationales when our assumptions are not applicable, require additional information to make a determination, or otherwise present unique circumstances that warrant additional discussion. For these species, we provide individual Integration and Synthesis summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination.

The fish species included in this Opinion, and our conclusions for each, are presented in Table 28. In addition to the species vulnerability assessments and summarized Environmental Baseline and Cumulative Effects information relevant to the analysis, we further discuss the effects of the action, and our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon in Appendix C. In this appendix, we present our grouped and individual integration and synthesis summaries for all fish considered in this Opinion.

Insects (Aquatic and Terrestrial)

This taxa group includes several orders of insects, including Coleopterans (beetles), Dipterans (flies), Hemipterans (true bugs), Hymenopterans (bees), Lepidopterans (butterflies and moths), Odonates (dragonflies and damselflies), and Orthopterans (grasshoppers). These species exhibit a variety of life history characteristics. All are generally short-lived, although some may live multiple years (e.g., at a larval stage). Some adult life stages may be very short, as brief as a few weeks. Most insect species considered in this Opinion are terrestrial. As a group, they inhabit numerous habitat types within the action area, depending on the species' life history requirements. The terrestrial insects are generally capable of flight, at least in adult life stages. Some adults are not able or naturally expected to move large distances and are restricted to small habitat patches separated by unsuitable habitat.

Some aquatic insects are fully aquatic, such as riffle beetles. Others have both aquatic and terrestrial life stages, including dragonflies, damselflies, stoneflies and similar species. For species with both terrestrial and aquatic life stages, juvenile and subadult (i.e., eggs, larvae, pupae) individuals generally live in aquatic habitats, while the adult life stage either exclusively or primarily occupies terrestrial habitats, depending on the species.

Given that invertebrates are the target species of methomyl, we assessed effects to each species in an individual Integration and Synthesis summary describing the species-specific information we considered to inform our rankings and determination of whether the proposed action was likely to jeopardize the continued existence of listed invertebrates. However, in analysis of species characteristics that influenced their exposure and effects, we found that species generally fell into similar categories as those species for which we grouped rationales. As such, we may consider such an approach for future analyses where we consider listed species in the same class as the target species for the pesticide being assessed.

Effects to Terrestrial Insect Species

Because methomyl is an insecticide developed specifically to kill insects, we expect that terrestrial insects are likely to experience high levels of mortality where exposure occurs.

Because all or large numbers of individuals exposed to methomyl will die across most uses, we do not generally anticipate there will be surviving individuals to experience sublethal effects.

Indirect effects (via dietary items) for terrestrial insects were analyzed similarly to the analysis for the species itself. We anticipate that risk will be high for terrestrial insects that consume other terrestrial invertebrate prey (e.g., American burying beetle, northeastern beach tiger beetle, and Puritan tiger beetle) and species that are reliant on other invertebrates for survival (e.g., myrmecophilous butterflies like the Fender's blue butterfly). This information was provided in the discussion for the species, and a similar effect was noted for the dietary item or obligate relationship. We were not able to directly assess impacts to other food resources (e.g., detritus) where we did not expect impacts from methomyl.

For species that prey on other invertebrates, we anticipate contamination or reduction of their forage base from methomyl exposure. Reduced food availability could result in substantial effects on individuals and populations of a species, particularly in habitats where food resources may already be scarce. For species with symbiotic relationships with other insects, we expect a loss of these species from methomyl exposure and a subsequent reduction in the proper development of the larvae of the listed species. For species that inhabit springs, streams, vernal pools, and other wetlands (e.g., Hine's emerald dragonfly and Comal Springs riffle beetle), we anticipate exposure from spray drift and runoff from use sites.

Effects to Aquatic Insect Species and Life Stages

For fully aquatic insect species, we anticipate methomyl will kill large proportions of individuals if exposed (e.g., Hungerford's crawling water beetle). There are low to high overlaps between the species' ranges and the action area for aquatic insects (0-18%) but overall, small percentages of their ranges have experienced past methomyl usage (0.6-4.5%). Because they are found in smaller flowing aquatic habitats, we expect methomyl concentrations to be high and thus we expect subsequent mortality to these species will be high where exposed.

Indirect effects were not analyzed for aquatic insects, based on the assumption that most indirect effects would involve invertebrate dietary items that would experience similar mortality to the listed species. We do not anticipate any adverse effects to detritus or plant-based foods (e.g., nectar, leaves, berries) from exposure to methomyl.

For terrestrial insect species with aquatic life stages (e.g., dragonflies, stoneflies), we anticipate mortality will vary by life stage and, where applicable, will be similar to what we described for fully terrestrial and fully aquatic species.

The invertebrate species included in this Opinion, and our conclusions for each, are presented in Table 28. In addition to the species vulnerability assessments and summarized Environmental Baseline and Cumulative Effects information relevant to the analysis, we further discuss the effects of the action, and our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon in Appendix C. In this appendix, we present our grouped and individual integration and synthesis summaries for all insects considered in this Opinion.

Mammals

All mammals are vertebrate endotherms distinguished from other animal taxa by possessing hair or fur and mammary glands for milk production in females. The species included in this group and our conclusions for each are presented in Table 28.

Terrestrial mammals in this Opinion include species from the orders Carnivora (carnivores), Chiroptera (bats), Eulipotyphla (shrews), Lagomorpha (rabbits), and Rodentia (rodents). Mammal species exhibit a variety of life history characteristics. Some species hibernate, such as the Virginia big-eared bat, and others like the northern long-eared bat migrate. Some species live in underground burrows, such as kangaroo rats and beach mice, while others spend most of the day in trees, like the ocelot. Species' ranges vary from only one location (e.g., riparian brush rabbit) to only a few locations (e.g., southeastern beach mouse), but others occur across many states (e.g., gray wolf, gray bat). Diet varies among species greatly as well. Some species are carnivores like the ocelot; the Buena Vista Lake ornate shrew and many bats are insectivores; pocket gophers and the Columbia Basin pygmy rabbit are herbivores; and other species, like beach mice, consume insects and vegetation.

Effects to Mammal Species

As described in the *Approach* section above, we used exposure and toxicity data, in combination with relevant life history information, to assess all mussels for effects to the proposed action. Effects to mammals from methomyl uses vary depending on the amount of overlap with methomyl uses, anticipated usage in the species' range, specific life history traits, and dietary items consumed. In general, we anticipate adverse effects will be in the form of mortality and sublethal effects to growth from the consumption of contaminated food items. We also anticipate there will be adverse effects resulting from a large reduction in the abundance of some prey species, which may result in mortality or reduced fitness from starvation.

In general, mammal species at the greatest risk of adverse effects, including mortality, are those that consume contaminated food on use sites that were recently treated with methomyl or contaminated prey that recently foraged on methomyl use sites. In contrast, mammal species that are not likely to forage on or near use sites or are not likely to exclusively consume prey species that have recently foraged on methomyl use sites are unlikely to die.

We do not anticipate sublethal effects to most mammal species are likely to occur. In most cases, mammals exposed to levels of methomyl that will cause sublethal effects will likely die before the onset of sublethal effects to growth or reproduction. One exception to this is mammals that consume contaminated grass off-field (i.e., up to 30 meters from methomyl use sites). Listed mammal species, such as the four species of pocket gopher (i.e., Yelm, Olympia, Roy Prairie, and Tenino), that are likely to consume grasses contaminated with methomyl off-field will not likely die but may experience reduced growth.

Indirect effects in the form of reduced abundance of food items will not occur for obligate herbivores (e.g., riparian woodrat, Columbia Basin pygmy rabbit, pocket gophers) as available toxicity data indicate that no adverse effects to plant survival, growth, or reproduction are likely to occur at environmentally relevant concentrations of methomyl. In contrast, we anticipate a large reduction in the abundance of insect species with exposure to methomyl, indicating that obligate insectivores (e.g., Indiana bat, gray bat, northern long-eared bat, Hawaiian hoary bat, Buena Vista Lake ornate shrew) are likely to experience high levels of prey loss with methomyl use. We expect high levels of mortality for vertebrate prey (e.g., small mammals, small birds) that forage on methomyl use sites and low levels of mortality for vertebrate prey that only forage off-field. As such, we anticipate listed mammal species that are reliant on prey species that are likely to occur on methomyl use sites (e.g., red wolf) may experience high levels of prey loss. In contrast, listed mammal species that can use a variety of food resources or those that are not likely to rely on prey that occur on or near agricultural areas (e.g., gray wolf and Gulf Coast jaguarundi) will likely only experience low to moderate levels of prey loss, resulting in low to moderate levels of indirect effects.

As discussed in the *Approach to the Effects Analysis* section, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We remove any species from the grouped rationales when our assumptions are not applicable, require additional information to make a determination, or otherwise present unique circumstances that warrant additional discussion. For these species, we provide individual Integration and Synthesis summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination.

The mammal species included in this Opinion, and our conclusions for each, are presented in Table 28. In addition to the species vulnerability assessments and summarized Environmental Baseline and Cumulative Effects information relevant to the analysis, we further discuss the effects of the action, and our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon in Appendix C. In this appendix, we present our grouped and individual integration and synthesis summaries for all mammals considered in this Opinion.

Reptiles

The reptile taxa group includes species from the orders Crocodilia (crocodiles), Squamata (lizards and snakes), and Testudines (turtles). Reptiles are tetrapod vertebrates, creatures that either have four limbs or, like snakes, are descended from four-limbed ancestors. Reptiles are ectothermic, relying on external heat sources (e.g., sunlight, warm surfaces) to regulate their body temperatures. Most reptiles are oviparous (egg layers; e.g., Alameda whipsnake, American crocodile, Plymouth redbelly turtle), although several species of squamates are viviparous (give live birth; e.g., giant garter snake). Reptiles do not have an aquatic larval stage. For those species that are oviparous, eggs usually have a soft leathery shell, although some eggs may have a hard shell. Eggs are usually laid on land in a nest covered with a layer of soil or vegetative debris or laid in some form of burrow. Most reptiles do not care for eggs once they have been deposited. However, American crocodiles for example, will guard their nests until the eggs hatch.

Reptiles can be found in a variety of habitats from sea level to mountainous terrain. Terrestrial and freshwater/estuarine reptiles can be found living along coastlines in mangrove swamps (e.g., American crocodile), in freshwater streams (e.g., yellow-blotched map turtle) and ponds or wetlands (e.g., bog turtles), to forests (e.g., Louisiana pine snake) and to drier environments including creosote bush scrub (e.g., desert tortoise) and wind-blown sandy environments (e.g., Coachella Valley fringe-toed lizards). Most listed reptiles have relatively small current ranges and are limited to one to a few counties within a single state (e.g., blue-tailed mole skink), while a few tend to have larger ranges (e.g., gopher tortoise). Reptiles face numerous threats including habitat destruction, fragmentation, land-use changes, changes in habitat suitability (e.g., timber practices, invasive species), disease, predation, loss of natural processes (e.g., fire suppression), and climate change. In addition, chemicals and pollution can alter the suitability of a species environment (e.g., water quality), and can affect the species itself by reducing its survival and reproduction. Clean air and clean water, and abundant, diverse, and healthy habitats are essential for listed reptile species to survive and recover in the wild.

<u>Effects to the Reptile Species</u>

As described in the *Approach* section above, we used exposure and toxicity data, in combination with relevant life history information, to assess all mussels for effects to the proposed action. Use areas for methomyl overlap with and/or occur adjacent to habitats within the ranges of nearly all the listed reptile species in this consultation. Exposure to this pesticide can result in direct mortality from the consumption of contaminated food resources, and indirect effects from the loss of important food resources that can lead to starvation, reproductive failure, site abandonment or other detrimental effects. The effects can vary greatly by species depending on the degree of overlap between pesticide uses and the species range, usage patterns, the species' preferred habitats, and the diet of the species considering how their food resources may be affected. Reptiles have a highly varied diet, from those species that are generally herbivorous (e.g., desert tortoise) to those species that eat primarily aquatic and terrestrial invertebrates, fish, and/or small mammals. Crocodiles are opportunistic feeders and will eat whatever they can catch, including snakes, fish, crabs, small mammals, turtles, and birds.

The majority of reptiles have high vulnerabilities due to small and isolated populations (e.g., blunt-nosed leopard lizard, San Francisco garter snake, St. Croix ground lizard, New Mexican ridge-nosed rattlesnake, flattened musk turtle, and many others); they are limited to one or a few populations, one or more populations are declining, and they face continuing threats such as habitat loss and exposure to environmental contaminants. Anticipated effects from methomyl use include mortality from consumption of contaminated food resources, and reduction in food availability, which vary from low to high levels depending on the where exposure occurs (i.e., on-field or off-field) and dietary preferences of the listed species. Expected usage within the species' range also varied for reptiles from extremely low levels (<1%) to high levels (29%). One factor that influenced the likelihood of exposure to methomyl was whether the species was expected to forage on methomyl use sites. When available information indicated individuals would not be exposed on use sites, the effects anticipated for these species were lower. For example, based on information from species experts, we determined that the northern Mexican garter snake was unlikely to enter and forage in most use sites and therefore limited the effects analysis to a small number of individuals anticipated to be exposed. Similarly for the bog turtle, information regarding their propensity to travel through and possibly rarely feed but not shelter or breed in agricultural areas was noted to reduce the possibility of individuals in the population to be exposed. Other species found to feed primarily on-field on dietary items that may accumulate methomyl (e.g., amphibians) were likely to have greater exposures (e.g., Eastern indigo snake, Alameda whipsnake, giant garter snake, narrow-headed garter snake, Eastern Massasauga rattlesnake).

As discussed in the *Approach to the Effects Analysis* section, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We remove any species from the grouped rationales when our assumptions are not applicable, require additional information to make a determination, or otherwise present unique circumstances that warrant additional discussion. For these species, we provide individual Integration and Synthesis summaries that further describe the information we considered to inform our rankings, as well as incorporate any additional, species-specific information that would be relevant to its final determination.

The reptile species included in this Opinion, and our conclusions for each, are presented in Table 28. In addition to the species vulnerability assessments and summarized Environmental Baseline and Cumulative Effects information relevant to the analysis, we further discuss the effects of the action, and our determination as to whether the proposed action is likely to jeopardize the continued existence of all the species within this taxon in Appendix C. In this appendix, we present our grouped and individual integration and synthesis summaries for all reptiles considered in this Opinion.

Snails

This taxa group is divided into two subsections: terrestrial and aquatic snails.

Effects to the Terrestrial Snail Species

We reviewed listed terrestrial snails that occur within the United States and its territories. The life history and distribution information vary substantially by species. Terrestrial snails inhabit a range of habitat types, including coastal dunes, talus outcrops and cliff faces, and trees of hardwood hammocks. Diets vary but include lichens, fungal mycelia, fallen leaves, and other detritus. For additional information, see the Status of the Species for these species and Environmental Baseline. Relevant life history traits are discussed below for a general understanding of ecology of each species.

In general, we do not anticipate effects to terrestrial snails as a result of exposure to methomyl. Data available from toxicity tests for terrestrial snails indicate that these species have relatively high tolerance to methomyl and have a subsequent low risk of mortality at estimated environmental concentrations (see section *General Effects to Terrestrial Invertebrates*).

Some species of terrestrial snails may also be considered lower risk due to their life history traits, such as the Virginia fringed mountain snail. The Virginia fringed mountain snail is fossorial (i.e., buried in soils along 6 miles of river bluffs), and we do not expect exposure to occur. O‘ahu tree snails are restricted to remnant native forest, in the deep interior on the highest ridges of the Ko‘olau and Wai‘anae ranges on the island of O‘ahu. We do not expect agriculture to be present in these areas, nor would the surrounding thick vegetation allow spray drift to penetrate the forest as it would act as a wind break. Similarly for the Sisi snail (*Ostodes strigatus*), which occurs on the ground in leaf litter within closed-canopy forests, any impacts from methomyl would be minimal due to their closed canopy forested habitat in the western portion of the island of Tutuila in American Sāmoa where there is very little agriculture. The Morro shoulderband snail is also less likely to be exposed to methomyl as their preferred habitat is in coastal dune, coastal dune scrub, and maritime chaparral plant communities in back dunes and stabilized dune systems, which are genearlly not near agricultural areas.

For other terrestrial snail species considered (e.g., Stock Island tree snail, Flat-spired three-toothed snail), their life histories may or may not include aspects that would preclude exposure; however, again, based on the terrestrial snail toxicity data, methomyl uses are not expected to result in the mortality of individuals of these species should exposure occur.

We estimated that methomyl uses would vary from approximately 0-25% for total overlap within the range of all listed terrestrial snail species and usage from approximately 0-10%. Due to this overlap, listed snails could experience high exposures from direct contact, except where exposure would not be expected due to a specific life history strategy, as described above.

Indirect effects (dietary items) for terrestrial snails were not anticipated from exposure to methomyl as most terrestrial snails feed on moss, algae, lichen, or other detritus.

Generally, we anticipate a low risk of mortality to all terrestrial snails based on their assumed tolerance to methomyl as determined from available toxicity data. For several of these species, we also anticipate that their life history strategy would lead to a low level of exposure (i.e., Virginia fringed mountain snail due to the low exposure anticipated in view of its burrowing life history).

Additional information for terrestrial snails is found in the *Status of the Species and Critical Habitat* (Appendix B) and the *General Effects* sections. *Integration and Synthesis* summaries are provided for each species (Appendix C). The species included in this group and our conclusions for each are presented Table 2.

Effects to the Aquatic Snail Species

We reviewed listed, proposed and candidate freshwater aquatic snails that occur within the United States. The life history and distribution information vary substantially by species. Freshwater snails inhabit a range of water bodies, from cave pools, springs, and small tributaries, up to large rivers. A threat common among many of the listed aquatic snails are the effects posed by dams (e.g., reduced ability to expand range and exchange genetic information between populations, and alternation of flow and water quality). Very little information on diets of aquatic snails is available. For additional information, see the *Status of the Species* for these species and *Environmental Baseline*. Relevant life history traits are discussed below for a general understanding of ecology of each species.

In general, we expect that aquatic snails will have a low risk of mortality as a result of exposure to methomyl based on acute toxicity data for freshwater snails to carbamate pesticides (see section *Effects to Aquatic Invertebrates)*. In particular, several species used in the SSD developed for carbaryl for mollusks were freshwater snails from multiple studies such as *Biomphalaria glabrata*, *Bellamya bengalensis*, *Pomacea patula,* and *Pila globose*. Due to the lower sensitivity to related carbamates exhibited by freshwater snails as compared to other aquatic invertebrates, aquatic snails were considered separately from other aquatic invertebrates in our analyses.

The endangered and threatened freshwater snails live in springs (e.g., Alamosa spring snail, Koster‘s spring snail, Chupadera spring snail, Lacy elimia, magnificent ramshorn) or or flowing waters such as streams and rivers (e.g., Anthony’s river snail, Snake River physa snail, Bliss Rapids snail, Tulotoma snail) and require very pristine water quality with specific levels of temperature, rates of water flow, oxygenation, and pH in order to thrive. For all uses, total overlap for the different species ranges varied from <1% to 87%. However, because of the relative tolerance of aquatic snails to methomyl, a low risk of mortality from methomyl use is anticipated for these species.

Indirect effects were not analyzed for aquatic snails, based on the assumption that most indirect effects for items considered for aquatic snails would involve dietary items that would not be impacted by methomyl exposure such as detritus, algae, or other phytoplankton.

Additional information for aquatic snails is found in the *Status of the Species and Critical Habitat* (Appendix B) and the *Effects to Aquatic Invertebrates* sections. The species included in this group and our conclusions for each are presented in Table 28.

Effects of the Action on Plants

In the Integration and Synthesis summaries (Appendix C), we evaluate the results of exposure to methomyl for each plant Assessment Group combination (as described in the *Toxicity* and *Effects of the Action* section of this Opinion). As described in the *Approach* section above, we used exposure and toxicity data, in combination with relevant life history information, to assess all plants for effects to the proposed action. In addition, we integrate the reproductive methods indicated by the species’ Assessment Group placement to determine how those characteristics (e.g., pollination vector, ability to reproduce vegetatively) may modify the plant species reproductive response to exposure and potential loss of their pollinators on the landscape.

As discussed in the *Approach to the Effects Analysis* section, after considering the plant species’ Assessment Group placement, we grouped species based on their vulnerability, exposure, and toxicity rankings, as species with the same ranking combinations likely have a similar risk profile and final determination. We remove any species from the grouped rationales when our assumptions are not applicable and provide an in-depth integration and synthesis summary where we discuss the necessary details needed to make a final determination. In situations where the combination of rankings indicates that additional scrutiny is required before a jeopardy determination is made, we provide a species-specific narrative that outlines the information that informed the rankings the species was assigned, as well as incorporates any additional, species-specific information that is relevant to its final determination. For plant species we considered certain additional life history characteristics that could modify the reproductive response of the plant species. These characteristics include its seed dispersal mechanism and whether it uses a few (specialist) or many (generalist) pollinator species for reproduction. We describe these characteristics in more detail below.

For each plant species, we considered all the information described above, and developed a rationale for the conclusion. Within each Plant Assessment Group, we documented our determinations for each endangered and threatened species. Proposed species, as well as candidate species, are included in the Assessment Group tables and individual rationales, although determinations for these species are provided as part of our conference biological opinion. Our analyses for these species are provided in the sub-appendices of Appendix C.

Effects to Plant Species

Mortality and Sub-lethal Effects[23]

We used the studies and data provided in EPA's BE (2021), that measured effects to plants from exposure to methomyl during post-emergent time frames and applied these data to all plants and lichens under consultation, as there are no data on the effects of methomyl to listed plant or lichen species (details available in General Effects – Plants). Studies on effects to terrestrial plants (monocot or dicot) reported from studies of post-emergent exposure to methomyl indicate there are no effects at the highest test concentrations used (see Plant Toxicity data in the General Effects to Plants section in this Opinion).

Effects to Pollinators and Seed Dispersers[24]

The vast majority of plant species covered in this consultation are pollinated by insects or a combination of insects and other animals. As described in detail in the *General Effects to Plants* section, impacts to insect pollinators and seed dispersers for listed plants can be significant because methomyl is designed to kill insects, including those that act as pollinators and/or seed dispersers of listed, proposed, and candidate plant species. Successful pollination leads to seed production and is a critical step in reproduction for many plant species. In addition, transfer of pollen between individual plants or populations of plants allows species to reproduce sexually, thereby recombining genes and allowing gene flow to occur. Gene flow is especially important in small, fragmented, or isolated populations where pollinating animals may provide the only connection among populations. Thus, loss of a portion of the pollinator community could lead to adverse reproductive effects in the form of decreased reproductive output for a listed plant species.

While available toxicity data indicate that insects, including those that act as pollinators and seed dispersers for listed plants, are sensitive to methomyl at estimated environmental concentrations and are likely to die from exposure on both application sites and adjacent areas exposed via drift, we expect insect species to exhibit a range of sensitivities to methomyl and do not anticipate the entire insect pollinator community will die.

In addition, we consider the following life history characteristics of each plant species to help evaluate the magnitude of indirect effects. We chose these characteristics as they can modify the

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[23] Mortality and sub-lethal effects correspond to risk assessment terminology of "direct effects."

[24] Effects to pollinators and seed dispersers correspond to risk assessment terminology of "indirect effects."

response of the plant species to loss of pollinators and/or seed dispersal vectors from methomyl exposure.

Dependence on biotic outcrossing and type of pollination vector (general reproductive method)

These characteristics are addressed through the Plant Assessment Groups. Generally speaking, plants that depend on insect outcrossing for successful reproduction are more likely to experience reproductive effects from loss of pollinators than plant species that can self-pollinate, use asexual forms of reproduction (i.e., vegetative reproduction), or that use abiotic pollination vectors. Likewise, a plant species that uses birds or mammals as pollination vectors are less likely to experience reproductive effects than those species reliant on insect vectors. This is because bird and mammal pollinators/seed dispersers are less sensitive to methomyl exposure than insects. While methomyl exposure in birds and mammals can cause mortality under specific circumstances (i.e., by consuming exclusively contaminated food items on or adjacent to methomyl use sites) we do not expect methomyl use is likely to appreciably diminish the availability of bird or mammal pollinators or seed dispersers. For species where the relationship with pollinators and seed dispersers is unknown, we make the conservative assumption that the species has a specialist-type relationship exclusively with insect pollinators and seed dispersers.

Seed Dispersal Vector

Successful seed dispersal is often a critical mechanism for the long-term persistence of many plant species. Dispersal enables plants to colonize additional suitable locations, thereby increasing the size of a population, or establishing new populations. Larger populations as well as well-developed meta-population dynamics among populations can maintain genetic diversity in these already rare plant species and prevent inbreeding depression among isolated populations. Declines in dispersal distance or ability may prevent these plant species from finding additional suitable sites to colonize and limit successful reproduction.

Plants utilize a variety of seed dispersal mechanisms. We do not anticipate negative effects from methomyl on abiotic seed dispersal mechanisms such as wind, water, and gravity, among others, as there is no reasonable, functional tie between methomyl use and these physical mechanisms of seed dispersion. However, many plant species rely upon biotic seed dispersal mechanisms; mainly internal or external transport by animal species. Typical taxa groups involved in seed dispersal include insects, birds, and mammals. Similar to pollinator species, plants that rely on insects for seed dispersal are more likely to experience adverse reproductive effects from seed disperser loss than those species that rely on birds and/or mammals due to the minimal effects of methomyl to these taxa groups as explained above.

Pollination or seed dispersal by one or a few species

Plants that depend upon a few or one specific pollinator species may see a disproportionately greater negative effect from the action since these plant species cannot utilize other insect species in the community for pollination if the specific pollinator they rely upon has been reduced or temporarily extirpated from the area due to methomyl use (See discussion; *General Effects to Plants*).

Plants that rely on a select few species of pollinators or seed dispersers (i.e., specialists) are likely to experience high levels of indirect effect as high mortality in a few insect pollinator species can significantly reduce pollination and seed dispersal. In contrast, generalist plants that can use a wide range of insect species are likely able to recover more quickly from temporary losses of some insect species, resulting in lower levels of indirect effects from the proposed action.

Effects to Plant Assessment Groups

Groups 1-3: lichens, ferns and allies, and conifers and cycads

As mentioned previously, these Assessment Groups contain plant species that do not use pollinators or seed dispersers for reproduction (e.g., lichens – group 1, ferns – group 2) or use abiotic vectors for pollination and/or seed dispersal (e.g., conifers – group 3). As such, EPA determined that the majority of these species had "No Effect" from the proposed action or the action was "Not Likely to Adversely Affect" the species. Therefore, most of these species are found in our *Concurrence* (Appendix A) and are not included in this Opinion. One exception is the fadang, a cycad species endemic to the island of Guam. This cycad uses wind for pollination, but can also use certain species of butterfly, therefore indirect effects to these pollinating butterflies are likely where exposure to methomyl occurs. However, overlap of the species range with methomyl is low (2.1%), the species can rely on wind for pollination in addition to butterflies, the species can also reproduce vegetatively, and seed dispersers are birds and mammals that are expected to experience minimal effects from malathion exposure. As a result, we expect minimal adverse reproductive effects to this species.

Groups 4 and 8: monocot and dicot flowering plants with abiotic pollination vectors

Plant species in these groups use abiotic vectors to accomplish pollination, such as wind or water. In addition, many of these species can reproduce vegetatively and disperse their seeds by wind or water. Thus, we anticipate most of the species in these groups will have minimal or no adverse reproductive effects from the proposed action since insects do not have a role in their life cycle. However, some species use mammals or birds as seed dispersal vectors. As explained previously, these taxa groups are expected to experience minimal effects from methomyl exposure, thus very minimal adverse reproductive effects are expected for plants that depend on them for seed dispersal. Example species include golden sedge, Solano grass, Maui reedgrass, and Hinckley oak. As a result, EPA determined that the proposed action was "Likely to Adversely Affect," or had "No Effect" on many of the species in these Assessment Groups, and they can be found in our *Concurrence* (Appendix A). EPA determined the proposed action is "Likely to Adversely Affect" the remaining species and they are found in the Plants Assessment Groups 3,4,&8 I&S Summary in Appendix C. These species are anticipated to have minimal adverse reproductive effects from the proposed action because they may rely on mammals or birds for seed dispersal but use abiotic vectors for pollination.

Groups 5 and 9: Monocot and dicot flowering plants that require outcrossing with biotic pollination vectors

Group 5 and 9 species, such as the Eastern prairie fringed orchid, persistent trillium, Monterey clover, Tobusch fishhook cactus, and many others use a variety of biotic pollinating vectors, and require outcrossing, the transfer of pollen between individuals, to reproduce successfully and maintain their populations over time. For successful outcrossing, individual plants need to be close enough spatially that their pollinators will be able to travel easily between plants of varying genetic composition. Anticipated adverse reproductive effects to these species vary widely depending on extent of exposure, presence or absence of the modifying life history characteristics described above, and their overall vulnerability. However, given most species in these groups rely on insect pollinator outcrossing for successful reproduction (only a few rely on birds and/or mammals for outcrossing), high levels of adverse reproductive effects are seen for a subset of these species. For example, the Kincaid's lupine exists only in the fragmented remaining grasslands of the Willamette Valley in Oregon. This area is highly agricultural, with high overlap and usage of methomyl use sites leading to significant loss of pollinators within a large portion of the species' restricted range. Given this and the species reliance on insects for pollination and outcrossing, and inability to withstand additional stressors (i.e., high vulnerability) we anticipate high adverse reproductive effects to this species.

Groups 6 and 10: Monocot and dicot flowering plants that can use self-fertilization and/or vegetative methods for reproduction

Group 6 and 10 species, such as the Pitkin marsh lily, Munz's onion, Tiburon jewelflower, marsh sandwort, and many others use a variety of biotic pollinating vectors to transfer pollen between individuals, but can also reproduce, at least partially, by self-pollination (i.e., pollen transfer within the same individual) or asexually (typically vegetative or clonal reproduction). As a result, they are less reliant on the pollinators within their range for successful reproduction and can withstand some loss of those pollinator communities. Many species in this group have low overlap and/or usage of methomyl across their range and combined with their ability to reproduce without pollinators are not expected to experience significant negative reproductive effects. However, to maintain their genetic diversity over time, some species in these groups still need pollinators to transport pollen (their genetic material) between individual plants. If these species also had high exposure and toxicity rankings, and/or possessed other life history characteristics that increased the potential for indirect effects (such as use of one or a few pollinator species), we anticipated high adverse reproductive effects for these species. For example, the Yadon's piperia is an orchid endemic to California and exists in a very restricted range in the Monterey peninsula. It also relies on a limited number of nocturnal hawk moths for pollination and experiences increased seed production when outcrossed versus when it reproduces using self-pollination. The high overlap of methomyl use sites combined with these factors leads us to anticipate high adverse reproductive effects for this species.

Groups 7 and 11: Monocot and dicot flowering plants that use biotic pollination vectors, but other characteristics of their reproductive mechanisms are unknown

Group 7 and 11 species, including the purple amole, Harper's beauty, autumn buttercup, tiny polygala, and many more use a variety of biotic pollinating vectors to transfer pollen between individuals, and a variety of seed dispersal vectors, but other aspects of their reproductive mechanisms are unknown. To be conservative, we assumed these species need outcrossing, at least partially, by their biotic vectors to reproduce successfully. As for the other Assessment Groups, anticipated adverse reproductive effects to these species vary widely depending on extent of exposure, presence or absence of the modifying life history characteristics described above, and their overall vulnerability. As such, those species with high overlap and/or usage, high toxicity rankings, those with modifying life history characteristics that increased their magnitude of indirect reproductive effects (such as requiring one or a few pollinator species), and/or high vulnerability factors (including pre-existing pollinator declines or reproductive failure) were anticipated to have high adverse reproductive effects. For example, the loʻulu, *Pritchardia maideniana*, is endemic to the island of Hawaiʻi and only approximately 89 individuals remain. In addition, the loʻulu experiences low pollination rates and an absence of seedlings and juveniles at most sites, indicating a pre-existing reproductive deficit. In combination with a high overlap and a moderate portion of the range expected to be treated with methomyl, we anticipate high adverse reproductive effects to the species.

All plants addressed in this Biological Opinion can be found in Table 28 above.

Critical Habitat Assessment

We assessed whether the registration of methomyl is likely to result in destruction or adverse modification of designated or proposed critical habitat. Destruction or adverse modification means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species (50 CFR 402.02). We analyze effects to critical habitat separately from effects to the species. Our analysis of destruction or adverse modification is centered around the exposure and adverse effects to the physical and biological features (PBFs) of designated and proposed critical habitat. The effects to PBFs are related to but are not always the same as effects to the species, and the species does not have to be present in critical habitat for adverse effects to the critical habitat to occur.

Critical habitat designation rules have included a variety of terms, such as “physical or biological features” (PBFs), “primary constituent elements” (PCEs), or “essential features” to characterize the key components of critical habitat essential for the conservation of the listed species. The 2016 critical habitat regulations (81 FR 7413) discontinue use of the terms PCEs and essential features and rely exclusively on the term PBFs originally used in the ESA 1986 amended regulations. However, the shift in terminology does not change the approach used in conducting a “destruction or adverse modification” analysis, which is the same regardless of whether the original critical habitat designation identified PCEs, PBFs or essential features. For those reasons, in this Opinion, we broadly use the term PBFs when referring to the key components of critical habitat that are described as essential for the conservation of the listed species in critical habitat designations as a standardized way to cover all features described by these terms.

When designating critical habitat, we first evaluate areas currently occupied by the species and consider what PBFs a species needs for life processes and successful reproduction. We only consider designating unoccupied areas as critical habitat when the amount of occupied areas would not be enough to ensure conservation of the species. For an unoccupied area to be designated as critical habitat, we must determine that there is a reasonable certainty that the area will contribute to the conservation of the species and that the area contains one or more of the PBFs essential to the conservation of the species. These areas may require special management considerations or protection, as described in designation rules. General PBFs of critical habitats include space for individual and population growth and for normal behavior; cover or shelter; food, water, air, light, minerals, or other nutritional or physiological requirements; sites for breeding and rearing offspring; habitats that are protected from disturbance or are representative of the historical, geographic, and ecological distributions of a species; and other features. Specific PBFs are also often included in critical habitat rules to describe habitat elements that are essential for the species based on the best scientific data available about the species' habitat, ecology, and life history. A feature may be a single habitat characteristic, or a more complex combination of habitat characteristics and functions.

For purposes of assessing whether a destruction or adverse modification determination is appropriate, the effects of the action, together with the status of critical habitat, the environmental baseline, and any cumulative effects, are evaluated to determine if the critical habitat range-wide would remain functional or retain the current ability for the PBFs to be functionally re-established in areas of currently unsuitable but restorable habitat, to serve its intended conservation and recovery role for the species. Destruction or adverse modification means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species. Such alterations may include, but are not limited to, those that alter the PBFs essential to the conservation of a species. To facilitate our analysis of the large number of critical habitat proposals and designations in this Opinion, we identified the types of PBFs that we anticipate will be negatively affected by the proposed action. We identified four categories of PBFs that are likely susceptible to the effects of methomyl:

(1) water quality,

(2) arthropods as prey, pollinators, or seed dispersers,

(3) non-arthropods, including prey, pollinators/seed dispersers and host fish, and

(4) general habitat function requiring no or low levels of chemical contaminants.

These types of PBFs are collectively referred to herein as the "relevant PBFs." We reviewed each critical habitat designation to determine if any relevant PBFs are identified as essential features of critical habitat for a listed or proposed species. For those critical habitats with rules that do not include specific PBFs, we assigned any relevant PBFs based on available information regarding specific needs of the listed species. Any critical habitats that do not contain relevant PBFs are given "no destruction or adverse modification" determinations as there are no links between methomyl exposure and impacts to critical habitat function. For each critical habitat containing at least one relevant PBF, we assessed the overall exposure of critical habitat to methomyl, the expected impact of methomyl exposure to each relevant PBF, and the expected overall impact to the conservation value of the critical habitat as a whole. We use this process to determine if a critical habitat is likely to experience destruction or adverse modification.

Exposure of Critical Habitat to Methomyl

Similar to the assessment of exposure to listed species, we consider the extent of overlap, the level of past methomyl usage on or adjacent to critical habitat, and any additional exposure considerations that would suggest our baseline assumptions are not appropriate for a given critical habitat (e.g., Census of Agriculture all insecticide usage, specific habitat characteristics that result in higher or lower levels of methomyl accumulation).

Overlap

Similar to our analysis of listed species, we use the overlap between the action area and designated critical habitat units as a metric of exposure. The EPA provided the overlap between methomyl use sites and designated or proposed critical habitats (i.e., on-field overlap) and the overlap between methomyl use sites buffered out to 90-meters and designated or proposed critical habitat units (i.e., off-field overlap). We determine the total overlap between critical habitat and the action area by summing the on- and off-field area overlaps for each relevant use type. Critical habitats with greater than 10% total overlap are assigned a high overlap score. Critical habitats with 5-10% overlap are assigned a medium overlap score, and critical habitats with less than 5% total overlap are assigned a low overlap score.

A notable difference between our assessment of overlap for listed species and their critical habitat is how we handle off-field overlap for aquatic species. In contrast to our analysis of aquatic listed species (which only use on-field overlap), we used both on- and off-field overlap in our assessment of critical habitats designated or proposed for listed aquatic species. This is due to the fact that critical habitat units designated or proposed for listed aquatic species are typically much smaller and more spatially refined than the species' ranges, which are typically at the HUC 12 watershed scale. Given that on-field overlap with critical habitat units does not account for other agricultural activity occurring nearby in the watershed, we include the 90-meter off-field overlap in our assessment of critical habitat.

Usage

Similar to our analysis of listed species, we use past methomyl usage data in our assessment of exposure to critical habitat. The EPA applied the level of past methomyl usage, as summarized by the State Summary and Usage Matrix (SUUM) in the BE, to calculate the percent of a critical habitat that is likely treated with methomyl annually. We determine the total portion of the critical habitat treated with methomyl annually by aggregating the percent critical habitat treated of all non-highly redundant crop groups (i.e., we sum all relevant crop type adjusted overlaps with either corn or soybean and either citrus or other orchards in our total usage calculations). Unlike in our analysis for listed species, the percent of a critical habitat likely to be treated annually is almost always the same as the percent overlap as the conservative assumptions used in the application of SUUM data coupled with the small area covered by critical habitat relative to the species' ranges often results in the suggestion of high levels of methomyl usage across critical habitats.

Similar to our analysis of listed species occurring entirely in California, we use data from the California Department of Pesticide Regulation's California Pesticide Use Report to determine the percent of critical habitat treated annually with methomyl in place of SUUM data when available and applicable. For critical habitats in California, we report the percent of critical habitat that has been treated with any pesticides, percent of critical habitat treated with any insecticide, and the percent of critical habitat treated with methomyl over a 10-year period (2012-2021). The EPA also provides estimates of the average number of growers/applicators that report pesticide usage within sections containing critical habitat in that same 10-year period, which we use as a surrogate metric for the potential variability in pesticide usage over time (e.g., a large number of growers reporting pesticide usage in a section containing critical habitat indicates less variability in the total area treated each year as changes in pesticide usage of a few growers is not likely to affect the proportion of the range treated).

We score total usage based on the total percent area that is likely to be treated with methomyl annually. Critical habitats that data indicate will have a large portion of their range (>10%) treated with methomyl each year are assigned a high usage score. Critical habitats that will have a medium portion of their range (5-10%) treated with methomyl each year are assigned a medium usage score, and critical habitats that data indicate will have a low portion of their range (<5%) treated with methomyl each year are assigned a low usage score.

Additional Exposure Considerations

When information on a specific species' use of critical habitat areas indicates that exposure assumptions are not likely true (e.g., for species known to avoid agricultural areas, or critical habitats located in protected areas where agricultural pesticide usage is not expected), we qualitatively incorporate that information into our exposure rankings. Some examples of relevant information include knowledge of a species' preferred habitat characteristics (e.g., species that only occupy waterbodies with high flow rates, species that only consume certain taxa of prey) or additional sources of usage data, such as the USDA CoA. We use the percent of a critical habitat treated with any insecticide as an additional line of evidence to characterize the level of exposure a critical habitat will experience. Given that these data are more spatially specific than usage data provided by the SUUM (with the exception of California, where data are available at a sub-county level) and covers all insecticides used (not just methomyl), we consider instances where the CoA reports low levels of usage for all insecticide within a species' range as strong evidence that methomyl usage is unlikely to exceed low levels of usage throughout the course of the action. When additional exposure considerations are available, we qualitatively adjust our exposure assessment to reflect this additional information as appropriate.

Adverse Effects to Critical Habitat PBFs

We characterize the expected impacts to critical habitats based on the anticipated level of adverse effects to PBFs. Our analysis of toxicity assumes critical habitats are exposed to methomyl at levels estimated by EPA's environmental exposure modeling and is focused on determining the level of adverse effect expected to occur once exposure has taken place. We compare estimated concentrations of methomyl in critical habitat to toxic effects reported in available toxicity studies of various taxa of organisms to determine the level of impact to relevant PBFs. We also include any additional considerations regarding a listed species' life history that provides additional context to the specific parameters that PBFs need to meet to maintain their function (e.g., how sensitive a listed species is to methomyl may influence the level of impact to a water quality PBF relative to another species).

Water Quality

Critical habitats that list water quality as a relevant PBF (e.g., low levels of chemical contaminants, high quality water) are likely to experience adverse effects from the presence of methomyl within waterbodies found inside critical habitat boundaries (whether through direct application or exposure through spray drift deposition or runoff). If a listed species is sensitive to chemical pollutants, exposure to methomyl could result in toxic effects to individuals. Thus, the presence of methomyl will likely result in adverse effects to the water quality PBF as individuals of the listed species may not be able to fully use or occupy critical habitat. The level of impact to water quality is dependent on the expected environmental concentration of methomyl likely to occur in critical habitat and the sensitivity of a listed species to methomyl.

We compare estimated environmental concentrations of methomyl provided by the EPA to available reference toxicity data for the most appropriate surrogate taxa or species to assess the anticipated impact of methomyl use on critical habitat water quality. The EPA models methomyl concentrations within different types of waterbodies (i.e., waterbodies with high flow rates, large volume waterbodies, low volume/low flow rate waterbodies) within each USGS HUC 2 watershed. We use the estimated concentrations of methomyl from the most appropriate waterbody type within the HUC 2 region where critical habitat is found. We used the aquatic invertebrate HC_{05} LC_{50} as the reference toxicity value to assess impacts to water quality in critical habitat designated for listed aquatic invertebrates. We created a dose-response curve for a generic fish using the HC_{05} EPA reported in the methomyl BE as a generic LC_{50} and a default slope of 4.5 to calculate the percent mortality within the range of EECs predicted to occur in the critical habitats of listed fish and aquatic phase amphibians.

We qualitatively rate the impact to the water quality PBF as high, medium, or low. In cases where the predicted level of methomyl in critical habitat waterbodies would cause high levels of mortality of individuals, we assign a high impact rating to the water quality PBF. We assign a low impact rating in cases where predicted methomyl concentrations are not likely to cause more than low levels of mortality. When a range of adverse effects are likely to occur (e.g., for species that can use habitats with a wide range of flow rates and depth profiles), we indicate that a range of adverse effects are likely to occur to emphasize that impacts to water quality are likely dependent on the specific areas within critical habitat where exposure occurs.

If available life history information indicates a listed aquatic species prefers a particular type of waterbody, we qualitatively adjust our assessment of adverse effects to weigh impacts to the waterbodies preferred by the species more heavily. Additionally, since we expect methomyl will rapidly degrade in natural environments (on the order of days to weeks), we anticipate water quality will recover once methomyl residues degrade. The time to recovery depends on many factors (e.g., how much methomyl accumulates in a waterbody, variations in temperature, flow rate and other environmental conditions, if repeated exposures are likely). We incorporate this information when available and relevant in our critical habitat determination rationales.

Arthropods as Prey, Pollinators, and Seed Dispersers

Critical habitats that list the presence of arthropods as a relevant PBF (e.g., insect or crustacean prey, insect pollinators or seed dispersers) are likely to experience adverse effects from methomyl exposure, whether through direct application or exposure through spray drift. If a listed species is highly reliant on arthropods, critical habitat exposure to methomyl would result in high levels of indirect effects to the species. Thus, the presence of methomyl will likely result in adverse effects to the arthropod PBF as individuals of the listed species may not have the necessary prey, pollinator, or seed disperser resources required for persistence, growth, or reproduction.

Based on available toxicity data, we generally anticipate arthropod species are sensitive to methomyl and are likely to experience high levels of mortality even at low levels of exposure. As such, we generally expect areas of critical habitat exposed to methomyl will experience large reductions in the abundance of arthropod prey, pollinators, and seed dispersers. Given this general sensitivity to methomyl, we anticipate most critical habitats that list the presence of arthropods as an essential component will likely be assigned a high impact rating to the arthropod prey/pollinator/seed disperser PBF.

However, we do not expect all arthropod species are equally sensitive to methomyl as variations in physiology, life history traits, and individual behaviors would result in a range of sensitivities to methomyl across multiple species. Thus, while we anticipate those areas of critical habitat exposed to methomyl will experience large reductions in the abundance of sensitive arthropod species, we expect other, less sensitive arthropod species would still be present and available within those areas of critical habitat to function as prey or pollinators/seed dispersers. We expect this range of sensitivities is most relevant for critical habitats designated for listed species that can capitalize on a wide range of arthropod species (e.g., generalist invertivores, plants that can be pollinated by a wide range of insect species), as these species can more easily switch to using less sensitive arthropod species as food or pollinators/seed dispersers. We incorporate this information into our critical habitat determination rationales as available.

Additionally, since we expect methomyl will rapidly degrade in natural environments (on the order of days to weeks), we anticipate the arthropod community will recover over time once methomyl residues degrade. The time to recovery depends on many factors (e.g., the ability of the affected species to rebound, the level of exposure within critical habitat, variations in environmental conditions like temperature or amount of sunlight, and if repeated exposures are likely). We incorporate this information when available and relevant in our critical habitat determination rationales.

Non-arthropods as Prey, Pollinators/Seed Dispersers, and Host Fish

Critical habitats that list non-arthropod species as a relevant PBF (e.g., mollusk and annelid prey, vertebrate prey, fish hosts) are likely to experience adverse effects from methomyl exposure. If a listed species is highly dependent on a specific non-arthropod species is sensitive to methomyl at estimated environmental concentrations, then the presence of methomyl within critical habitat will result in high levels of indirect effects to the species. Thus, exposure to methomyl may result in adverse effects to the non-arthropod PBF as individuals of the listed species may not have the necessary prey or host fish resources necessary for persistence.

The overall impact of methomyl to non-arthropod prey will vary greatly between the different taxa included in this PBF category. We compare estimated environmental concentrations generated by the EPA to available toxicity data provided in the methomyl BE to determine the overall effect to the non-arthropod PBF. Available toxicity data indicate that mollusk species are not sensitive to methomyl. As such, we anticipate mollusk prey within critical habitat are not likely to experience more than very low levels of adverse effects, even at the highest concentrations of methomyl predicted to occur in the environment. As such, critical habitats that only list mollusk prey species as an essential feature are likely to be assigned a low impact rating for the non-arthropod PBF.

Vertebrate prey and host species will experience a wide range of adverse effects from methomyl exposure depending on the exposure conditions. Fish and aquatic phase amphibian prey and fish host species are likely to experience high levels of mortality in aquatic habitats that are shallow or have low flow rates. In contrast, fish and aquatic phase amphibian prey and fish host species are not likely to die and only low levels of sublethal effects to growth and reproduction in areas of critical habitat that have high flow rates or are large in size. Critical habitats that list fish or aquatic phase amphibian prey or fish host species as an essential feature may be assigned a low to high impact rating for the non-arthropod PBF, depending on the specific habitat characteristics the listed species needs. We use information about the listed species' preferred aquatic habitat conditions (when that information is available) to determine the most relevant exposure conditions and the associated impact rating to the fish or amphibian prey base or fish host community.

In our analyses of impacts to fish host species in particular, we qualitatively adjust our impact rating depending on the range of fish hosts the listed species can use to successfully reproduce. While we anticipate a high level of mortality of fish species in certain types of waterbodies, we do not anticipate all fish species are equally sensitive as variations in physiology, life history, and individual behavior will result in differing sensitivities to methomyl. As such, while we anticipate a large reduction in the abundance of sensitive fish host species in areas of low flow or low water volume, we do not anticipate there will be complete mortality of fish hosts and that there will still be some hosts available for listed bivalves to use. We anticipate the fish host PBF in critical habitats designated for listed bivalves that can use a wide range of fish host species will be more robust to adverse effects of methomyl as there is a higher probability that the remaining, less sensitive fish species can be used as hosts for their glochidia. In contrast, the non-arthropod PBF in critical habitat designated for listed bivalve species that are fish host specialists (i.e., can only use a narrow range of host species) may still experience high levels of impacts despite there being a reduction in the abundance of only some fish species. We incorporate this information into our rationale as information is available.

Terrestrial vertebrate prey will experience a wide range of adverse effect from methomyl exposure depending on where the prey is exposed. Terrestrial vertebrate prey of all taxa (i.e., mammals, birds, amphibians, and reptiles) are all likely to experience high levels of mortality when individuals forage on contaminated food items on use sites within a short period after methomyl applications are made. In contrast, we anticipate only low levels of mortality and sublethal effects are likely to occur in terrestrial vertebrate prey that consume contaminated food items off-field. For our analyses of adverse effects to terrestrial vertebrate prey, our default assumption is that the prey species are likely to consume contaminated food on- and off-field. As such, we assign a range of low to high impact ratings for the non-arthropod PBF for critical habitats that list terrestrial vertebrate prey as part of the non-arthropod PBF. In cases where available knowledge of a listed species' prey indicate that individuals have increased or decreased likelihood of occupying or foraging on or near methomyl use sites, we qualitatively adjust our rating to weigh on- or off-field impacts to vertebrate prey as appropriate.

General Habitat Function

Critical habitats that require low levels of chemical contaminants for proper function as a relevant PBF (i.e., general habitat function PBF) are likely to experience adverse effects from the presence of methomyl within critical habitat boundaries. If a listed species is sensitive to chemical pollutants, exposure to methomyl residues on various surfaces within critical habitat would result in toxic effects to individuals, preventing them from using critical habitat. Thus, the presence of methomyl will likely result in adverse effects to the habitat function PBF as individuals of the listed species may not be able to fully use or occupy critical habitat. The level of impact to habitat function is dependent on the expected environmental concentration of methomyl likely to occur and the sensitivity of a listed species to methomyl.

We compare estimated environmental concentrations of methomyl provided by the EPA to available reference toxicity data for the most appropriate surrogate taxa or species to assess the anticipated impact of methomyl use on critical habitat function. We used the lowest invertebrate LD_{50} as the reference toxicity value to assess impacts to water quality in critical habitat designated for listed aquatic invertebrates. For our assessment of critical habitats designated for listed terrestrial vertebrates, we created a dose-response curve for a generic mammal and bird (which we applied to listed reptiles and terrestrial phase amphibians) using the lowest surrogate LD_{50} EPA reported in the methomyl BE for each taxa and a default slope of 4.5 to calculate the percent mortality within the range of EECs predicted to occur in the critical habitats of listed terrestrial vertebrates.

We qualitatively rate the impact to the habitat function PBF as high, medium, or low based on the level of adverse effects likely to occur at predicted environmental concentrations. In cases where the predicted level of methomyl in critical habitat would cause high levels of mortality of individuals, we assign a high impact rating to the habitat function PBF. We assign a low impact rating in cases where predicted methomyl concentrations are not likely to cause more than low levels of mortality. If available life history information indicates specific behaviors or habitat preferences that would alter the likelihood of exposure to methomyl residues (e.g., individuals are attracted to agricultural areas or individuals tend to aggregate in areas away from cultivated lands), we qualitatively adjust our assessment of adverse effects to weigh impacts to the habitat function PBF based on the likely exposure of individuals to methomyl residues within critical habitat.

Since we expect methomyl will rapidly degrade in natural environments (on the order of days to weeks), we anticipate habitat function will recover over time once methomyl residues degrade. The time to recovery depends on many factors (e.g., the level of exposure within critical habitat, variations environmental conditions like temperature or amount of sunlight, and if repeated exposures are likely). We incorporate this information when available and relevant in our critical habitat determination rationales.

Critical Habitat Determinations

To determine the overall impact of the proposed action to designated or proposed critical habitat, we assess the impact score of each relevant PBF alongside the exposure ranking to determine both the overall adverse effect of methomyl exposure and the footprint of the anticipated adverse effect across the entire critical habitat. Our results can be found in Appendix D. Critical habitats that had the same or very similar rationales for their conclusion were grouped together to increase efficiency and avoid repetition. We considered relevant information and data unique to each critical habitat when assigning critical habitats to groups and incorporated into the rationales as appropriate. Critical habitats with rationales that did not fit in a group, or warranted additional discussion, have a separate rationale.

We remove any critical habitats from the grouped rationales when our assumptions are not applicable and provide an in-depth analysis to provide the necessary details needed to make a final determination. For instance, we removed critical habitats from grouped rationales when we determined that CalPUR data did not have a sufficient sample size within the sections containing a critical habitat to confidently conclude that exposure was unlikely to occur. In other cases, our analysis of the species highlighted additional concerns that warranted additional scrutiny in the species' critical habitat even if there is low overlap between critical habitat and the action area or if data from the Census of Agriculture indicated low levels of past usage. These critical habitats have an individual analysis and write-up in Appendix D.

Assumptions and Uncertainties for All Species in this Consultation

There are many uncertainties and assumptions that accompany an analysis of this size and scope. The manner in which chemicals can move through the environment and interact with other biotic and non-biotic stressors is highly complex and necessitates that we focus our analysis on those factors that are identifiable, reasonably predictable, likely to influence whether species are affected, and for which we have data to characterize those effects. As such, we have made assumptions about certain elements of the analysis for which we have limited abilities to address directly due to lack of relevant data or appropriate models. Below we identify several assumptions and uncertainties we have considered in our analysis for the overall approach, as well as specific to the effects analysis. In some instances, we are aware that certain assumptions, when taken alone, may under-predict effects to listed species. However, by using conservative assumptions in other areas that may overestimate effects in some instances, we expect that we are capturing the overall breadth of effects to species and critical habitat in evaluating whether EPA's action is likely to jeopardize listed species or adversely modify critical habitat. For example, we lack data to quantitatively assess the effects of methomyl to individual species in combination with other stressors in the environment (e.g., temperature, other chemicals;

exposure to multiple stressors). However, by making conservative assumptions about exposure to methomyl at maximum environmental concentrations and looking at the full extent of lethal and sublethal effects, we expect that we are capturing the breadth of effects to species, including those that may manifest at sub-maximal concentrations, but in combination with other environmental stressors. In some cases, we are unable to predict whether individual assumptions will under- or over-predict effects to listed species and critical habitats. Overall, we expect that when taken together, the assumptions we have made are based upon the best scientific and commercial data available, capture the magnitude and extent of the effects of the action, and are otherwise consistent with the ESA and its implementing regulations.

Surrogate Data

In the *General Effects* section, we briefly discuss how we used toxicity data to analyze effects to listed species. Very few listed species have toxicity data specifically addressing effects from methomyl. We therefore discuss toxicity data that are available for the taxa groups and the decision process we employed to arrive at the toxicity values we used for our effects analyses. Where toxicity data are lacking, such as for reptiles and amphibians, we discuss the use of toxicity data from other taxonomic groups in the *Effects to Reptiles*, *Effects to Terrestrial Amphibians, and Effects to Fish and Aquatic-Phase Amphibians* sections. More specifically, we used fish and bird data for aquatic and terrestrial amphibians, respectively and bird data for reptiles. For amphibians and reptiles, data are also lacking to convert doses and dose-based endpoints across individuals, as discussed above. For aquatic plants, toxicity data are reported as mg a.i./L, which are differing units from how terrestrial plant toxicity data are provided (lbs a.i./acre). Aquatic plant toxicity data are most often based on studies on non-vascular algae which may or may not be applicable to listed aquatic vascular plants to assess effects. For many plants, often the only correlation between tested species and the listed species is that they share a seed growth mechanism, such as if both the listed and test species are dicots. However, there are several listed ferns and other allies, conifers/cycads, and some lichens that would not be comparable to any tested species, and we use available toxicity data from dicot species for these non-flowering plants.

In addition, there are several data gaps for basic biology for plant and animal species covered under this consultation that add additional complexity to this analysis. For example, there is often little to no available data regarding different types of effects (e.g., sub-lethal, effects to prey base, effects to pollinators, direct impacts to flowering plants) of pesticides on species that are rare, highly specialized, and occur in specialized habitats. The toxicity data we have chosen to use, and have discussed in depth in the general effects to taxa sections, is the best available information we have regarding the impacts of this pesticide to listed species. These data often represent one or more species within a taxa group that are applied to all species within that taxa (e.g., honey bee toxicity data to address effects to all insects) or a taxa group for which data are lacking (e.g., fish toxicity data to address effects to aquatic-phase amphibians). We also explain why certain data were used for certain species (e.g., carbaryl data for mussel species) in the general effects to taxa sections as well.

Estimated Environmental Concentrations

For this analysis of the effects of methomyl to different taxonomic groups in this Opinion, we assume that individuals will be exposed to a range of modeled annual maximum pesticide concentrations for a species that inhabits higher flow/volume waterbodies or if they inhabit low flow/volume waterbodies or both, the range of EECs always provides for a conservative assumption for the concentrations of the pesticide in the given waterbody. In addition, exposures are based on pesticide crop usescenarios that generate the highest EECs, which also may overestimate effects. For aquatic species, distribution within aquatic habitats is assessed based on very generic habitat flow volumes and rates and may over- or underestimate exposures to listed fishes, crustaceans, aquatic insects, aquatic snails, and mussels. However, effects are limited to a single exposure of methomyl, when, in reality, individuals may be exposed more than one time to concentrations that could cause effects; thus, this assumption may also underestimate effects.

This Opinion operates on the assumption that all use sites will be treated at the same time, and all individual members of a listed species within the use overlap will be exposed to peak applications, once a year. In reality, we do not expect all use sites will be treated at the same time, resulting in every individual member of a species that overlaps the area being exposed to peak applications and, therefore, we acknowledge this approach will overestimate exposure. On the other hand, some areas may have additional peak events occurring in a year, and, therefore, the above assumption may underestimate exposure. The assumption that use area represents where a given pesticide will be applied, for a small ranging species, may over- or underestimate the exposure. The assumption that the use scenario generating the highest combined application rates should represent exposures resulting from a given CDL use layer (e.g., vegetables and ground fruit) may overestimate effects. These assumptions vary in whether they over or underestimate exposures depending on the analysis being done. However, overall, our analysis in this Opinion contains reasonable assumptions in determining whether the proposed action is likely to jeopardize species or adversely modify critical habitat.

Species-specific Information

Where more life history information was available for a species, it allowed us to make fewer assumptions about how the species may be exposed to methomyl. Specifically, knowledge of the types of habitats used by individuals of a species and their tendency to be found near and within use sites allowed us to better predict whether individuals would be exposed to methomyl and, if so, the magnitude of that exposure. However, the extent of this information, and our ability to project the likelihood of exposure in this manner varied across species. This lack of information could result in an overestimation or underestimation.

An individual is assumed to occur at a single location and cannot be exposed to pesticides at other locations or at other times. Exceptions to this include migratory birds, migratory fish, or migratory mammals where additional exposure could be realized along a migratory path (e.g., whooping crane, Gulf sturgeon, some bat species). This may overestimate exposure for mobile species that may not be present during application or underestimate exposure for mobile species that forage on more than one treated field or are exposed during different stages of migration.

Effects to Critical Habitat

For aquatic and terrestrial animal species that have critical habitat, where physical and biological features (PBF, or other features as defined in Critical Habitat Approach to the Assessment) are discussed, our analyses assume that if a pesticide will impact these features now or preclude their development in the future (i.e., prey items, water quality, pollinators, etc.), then the critical habitat would be negatively affected. If no specific PBFs that would likely be affected by exposure to pesticides have been identified in the critical habitat rule, then the critical habitat would not be impacted (e.g., if PBFs pertain to features that are not susceptible to pesticides, such as geological features such as talus slopes, sandy areas in pine rockland, moist, well-drained moss mats growing on rocks and boulders, or plant structures such as nesting trees, etc.).

Species Range Maps

One of the main uncertainties within the analysis for this consultation is the reliance on current ranges for each species that may not accurately reflect the species' actual distribution within those mapped ranges. Often these ranges are defined as entire counties or smaller subunits (e.g., quads, HUCs) within which the species is known to occur but do not identify actual areas of suitable habitat where the species is likely to be found. Through internal Service efforts to refine species ranges, we were able to refine and improve many of the existing current range maps, either by reducing the number of overall counties or by mapping at a sub-county level (e.g., by habitat associations for Hawaiʻi plants), based on the best scientific and commercial data available at the time. However, even refined range maps may include areas not specific to species' habitat requirements.

Without detailed information on where a species can be found, our assumption for this assessment is that each species analyzed is uniformly distributed within its range. This may overestimate or underestimate our understanding of where a species is found. Exceptions to this assumption were for species where information is known based on specific data from Service Recovery Plans or 5-Year Reviews (e.g., Moapa Dace). Some species will have information where specific segments of the range have been identified for recovery, for critical habitat, or for other specified uses, and the locations of populations of the species are known within these areas.

Use sites

For terrestrial and aquatic species, we assume the GIS information we have for all methomyl use sites is accurately represented within the species' range because this is the best information available to us. This may over or underestimate the presence of use sites.

Pesticide Usage Information

Pesticide usage data is derived from a variety of sources that inherently vary with respect to the reliability, accuracy, and specificity of the data being reported. We assume these data may over- or underestimate the actual pesticide usage based on the source. Kynetec agricultural data may over- or underestimate actual usage due to the methodology behind how these data are collected, how they are applied within a given state where a crop may be grown, and how they are statistically analyzed. The California pesticide use reporting data from California's pesticide use reporting (PUR) program is a very comprehensive pesticide usage database (CDPR 2020). Under the program, all agricultural pesticide use must be reported monthly and all agricultural uses can be evaluated on a scale as precise as a county-township range section (a section being a land unit which constitutes one square mile or 2.6 square kilometers, containing 640 acres) and as broad as the county level. These data are generally very reliable, but even section-level analysis may include areas that are not within the species' range, and uncertainties in the reporting exist. As such, while have greater confidence in these data, we acknowledge that it may still over- or under-estimate exposure to listed species.

Spray Drift Effects

Spray drift is a primary route of offsite transport of pesticides when applied to use areas. For all species, spray drift will increase the area of overlap with the species range, and is particularly important for species that are not anticipated to enter use sites (i.e., plants), as it may represent the only exposure to methomyl that is likely to occur. However, it is important to note that spray drift areas and areas for different uses can overlap with one another, depending on their proximity on the landscape. For this reason, combining areas from different uses where spray drift exposure could occur without accounting for this proximity is likely to overestimate the total overlap with the species range.

Other Considerations for Plants

For plants, we used the best available data to determine if there are any species that have obligate pollinators or seed dispersers, and we attempted to determine what general taxonomic group those pollinators or seed dispersers occur within. However, we note that for many plant species, there is little to no information regarding the specific pollinators and dispersers that frequent a species' flowers and fruits. Additionally, there is little specific information regarding the movement distances and patterns for many pollinators and seed dispersers. While there are often general month ranges available for floral periods for each species (e.g., flowers present from May to June), there is little to no information available for floral duration and reproductive periods within the floral period for many plant species. This is an important consideration, as the loss of pollinators during peak blooms periods can lead to reduced plant reproduction and dispersal.

Impacts to soil microbial communities and mycorrhizae have been noted for pesticides. However, there is little to no information available regarding the degree of impact to the soil microbial community or mycorrhizae after pesticides are applied. Additionally, for many species where we may know or assume there is a mycorrhizal associate (i.e., orchids), the identity and basic biology of that associate species is often unknown.

Summary

We acknowledge that many of the assumptions we have made in this analysis have the potential to under- or overestimate the extent of effects to listed resources. However, we have provided an explanation of why we made the assumptions and addressed uncertainties and have endeavored to clarify and frame our assumptions to adequately support our understanding of the effects of the action. Table 29below provides a summary of our main assumptions and uncertainties, including whether there is an underestimate, overestimate, or an unknown risk of overestimating or underestimating effects to the species associated with each.

Table **29**. Assumptions and Uncertainties for the Effects Analysis

Methomyl DRAFT
Assumptions and Unc

CONCLUSION

The proposed registration that is being reviewed for methomyl is likely to jeopardize the continued existence of 82 species. Our Opinion considers 1,020 species (see individual taxa/group tables in the *Integration and Synthesis* section of this Opinion). Of these, one species is included as part of conference opinions (one is proposed and it is a candidate species). The species that are likely to be jeopardized generally have high vulnerabilities (e.g., they are represented by a single or a few populations, their populations are declining, populations are small or isolated and fragmented across their range). In addition, these species are likely to have higher overlapping use sites across their ranges, and we anticipate medium to high methomyl usage within their respective ranges. Therefore, we anticipate exposure will result in levels of mortality, and/or effects to food resources or pollinators that are likely to result in species-level effects. Direct mortality effects are anticipated, ranging from a few to many individuals of some species being impacted, while others are expected to have reduced fitness and loss of long-term viability due to loss of prey resources, host fish (for mussels) and pollinators (for plants). In some cases, individuals of some species may experience multiple effects concurrently (e.g., loss of food resources, direct effects) within a given application area. After adding the effects of the action and cumulative effects to the environmental baseline and in light of the status of these species, it is the Service's opinion that the registration of methomyl is likely to appreciably reduce the survival and recovery and thus jeopardize the continued existence of these species.

The proposed registration of methomyl is not likely to jeopardize the continued existence of 938 species (see individual taxa/group tables in the Integration and Synthesis section of this Opinion). Of these, two are subject to conference opinions (both are proposed endangered). These species have vulnerabilities ranging from low to high, represented by a single, few or many populations, with populations that may be declining, stable or increasing. While most listed species have isolated and fragmented populations, some of these species are less vulnerable to overall threats. Although many of the same effects mentioned above for species likely to be jeopardized by the action also pertain to these species, these effects are generally lower in magnitude, these species' ranges have lower overlaps with use sites, and methomyl usage is low to medium within these species' ranges. While we do anticipate that a number of individuals within each species are likely to be lost to mortality, be subjected to sublethal effects, or have a reduction in food resources or pollinators, we do not anticipate species-level effects, and, therefore, we do not anticipate that the registration of methomyl will jeopardize the continued existence of these species.

Destruction or adverse modification means a direct or indirect alteration that appreciably diminishes the value of critical habitat as a whole for the conservation of a listed species.

Through this consultation, we determined pertinent elements of the PBFs of proposed and designated critical habitats that are susceptible to effects from methomyl. These elements fall within the following categories: (1) water quality for aquatic or water-dependent species, or conditions related to pollution-levels for terrestrial habitats to function for the species (habitat function), (2) arthropods as prey (e.g., for insectivorous species), (3) non-arthropods as prey for omnivorous or carnivorous animal species, pollinators/seed dispersers for plants, and host fish for mussels, and (4) insect pollinators and seed dispersers for plants. The degree to which these PBFs would be affected by methomyl and the consequences for each critical habitat was evaluated, and our assessments and conclusions are included in Appendix D.

The Opinion covers critical habitats for 271 species (see individual taxa/group tables in the *Integration and Synthesis* section of this Opinion). There were no proposed critical habitats. Based on the critical habitat analysis described above and presented in Appendix D, adverse effects are anticipated for some critical habitats. We anticipate that those adverse effects would rise to the level where they are likely to appreciably diminish the value of the critical habitat as a whole for the conservation of the listed species. Therefore, it is the Opinion of the Service that the proposed action is likely to result in the destruction or adverse modification of critical habitat for 34 species.

For the remaining 237 critical habitats, the proposed registration of methomyl is not likely to destroy or adversely modify proposed or designated critical habitat. Based on the critical habitat analysis described above, we do not anticipate that the proposed action would adversely impact critical habitat to a level that would appreciably diminish the value of those critical habitats for the conservation of their respective species. While adverse effects are anticipated for some critical habitats, they do not rise to a level of destruction or adverse modification of the critical habitat as a whole. Therefore, it is the Opinion of the Service that the proposed action is not likely to result in the destruction or adverse modification of critical habitat for 237 species.

REASONABLE AND PRUDENT ALTERNATIVES

Regulations (50 CFR §402.02) implementing section 7 of the Act define reasonable and prudent alternatives (RPAs) as alternative actions, identified during formal consultation, that: (1) can be implemented in a manner consistent with the intended purpose of the action; (2) can be implemented consistent with the scope of the action agency's legal authority and jurisdiction; (3) are economically and technologically feasible; and (4) would avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat.

As this is a draft Opinion, we will continue to work with the action agency (EPA) and the applicants (registrants) to develop and finalize RPAs that meet the standards above prior to finalizing the Opinion, consistent with 50 CFR §402.14(g)(5). In the interim, for further discussions with EPA and the applicants (registrants), we are providing general categories of RPAs that we will consider prior to finalizing the Opinion and completing consultation and that would be tailored to the needs of specific species and critical habitat to avoid the likelihood of jeopardy and destruction and adverse modification[25].

1. Refinement and modification of the label through ‘Bulletins Live! Two’ to reduce risks on use sites where listed (or proposed) species or designated (or proposed) critical habitat occurs. These clarifications and modifications could include:
    a. Reducing the allowable application rates or frequency of use;
    b. Clarification or refinement of allowable labeled uses, including removing any uses or geographical areas where usage is not anticipated;
    c. Seasonal timing restrictions to avoid exposure of species during critical life history stages (e.g., breeding, rearing, overwintering);
    d. Daily timing restrictions to avoid exposure of species during the time(s) of day when they would be most susceptible to exposure;
    e. Increased buffer widths between use sites and sensitive habitats (e.g., wetlands, groundwater recharge areas) or other areas important to sensitive life history stages of listed species to reduce the potential for, or magnitude of, exposure;
    f. Elimination or reduction of application method (e.g., aerial) in geographical areas where such methods are known to be seldom utilized (e.g., Hawai‘i) or for the avoidance or minimization of exposure for species or critical habitats;
    g. Incorporation of a rainfast (i.e., exclusion of application for a period when rain is forecast) to avoid or minimize runoff; and/or
    h. Any additional measures that could further minimize spray drift and runoff (e.g., related to application method, nozzle size, rainfall, wind speed or other factors).
2. Removing high risk areas within species ranges or critical habitats from allowable pesticide use areas or establishing “No Spray Areas.”
3. Planting or retaining vegetation adjacent to active fields to reduce the risk of spray drift or runoff to potentially occupied sites.
4. Working with Stakeholders and Agencies to help determine how to offset impacts on a site- or species-specific basis, as is appropriate for the affected species (e.g., reintroduction of listed species away from active agricultural fields or other intensive spray areas, listed plant propagation and out-planting, habitat protection and restoration, or other activities that support species conservation and recovery).

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[25] We also recognize that EPA and the applicants may consider whether they might prefer to incorporate such measures into the project description of the proposed Action evaluated in this draft document prior to finalization of our final Opinion to help avoid and/or minimize the exposure of listed species and designated critical habitats to methomyl, thereby reducing the risk to the species or critical habitat to a point where jeopardy and destruction or adverse modification can be avoided.

INCIDENTAL TAKE STATEMENT

Section 9 of the ESA and federal regulation pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. *Harm* is defined by the Service as an act that actually kills or injures wildlife. Such act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavior patterns, including breeding, feeding, or sheltering (50 CFR 17.3). *Harass* is defined by the Service as an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering (50 CFR 17.3). Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), taking that is incidental to and not intended as part of the agency action is not considered to be prohibited taking under the ESA provided that: 1) the action is not likely to jeopardize the continued existence of listed species or implements a reasonable and prudent alternative to avoid the likelihood of jeopardy, and 2) such taking is in compliance with the terms and conditions of this Incidental Take Statement.

AMOUNT OR EXTENT OF TAKE

We are deferring a finer-scale description of the amount or extent of take, as well as any related Reasonable and Prudent Measures and Terms and Conditions, until we finalize the biological opinion, pending further coordination with the EPA and registrants. We generally described the types of anticipated incidental take in the *Integration and Synthesis* section and its appendices and our *Conclusion* section above. Briefly we anticipate the proposed action will result in the loss of (mortality) or sublethal effects to (i.e., impacts to growth, reproduction, or behavior) individual animals, the numbers of which will vary by species. Some species will also experience impacts to their prey or forage base, or to other species or habitat on which they depend, which will impact their growth, reproduction, and/or survival. As with mortality and sublethal effects, the numbers of individuals affected by impacts to their prey or forage base and the anticipated degree of such effects will also vary by species.

CONFERENCE REPORT

CONFERENCING ON PROPOSED AND CANDIDATE SPECIES AND PROPOSED CRITICAL HABITAT

Formal consultation was undertaken for most endangered and threatened species and designated critical habitat, and these listed resources are addressed in this Opinion. The Act requires a federal agency to conference if their action is likely to jeopardize a species proposed for listing or that is likely to destroy or adversely modify critical habitats proposed for designation (ESA 7(a)(4)). Recommendations resulting from that conference are advisory (i.e., they are not required) because the species or critical habitat is the subject of a proposed rule and the prohibition against jeopardy and adverse modification under ESA section 7(a)(2) only applies to listed species and critical habitat designations. Conferencing can be conducted informally or can follow the format of a formal consultation under 7(a)(2).

In this case, because the duration of the proposed action is 15 years, the Agencies agreed it would be prudent to use this opportunity for EPA to conference with the Service on the effects to species that are proposed for listing and critical habitats proposed for designation. In addition, although not required, the Agencies agreed to evaluate candidate species that may be proposed in the near future in this Conference. By conferencing now, any future consultation required under 7(a)(2) when a species listing or critical habitat designation is finalized may be streamlined, and in some cases, conferences can satisfy the consultation requirements under 7(a)(2). Using this approach, in this conference, we found the proposed action is not likely to jeopardize any proposed or candidate species or result in the destruction or adverse modification of any proposed critical habitat designations.

Upon completion of this conference, EPA may elect to adopt any of the recommendations provided by the Service, including any of the reasonable and prudent measures to minimize incidental take for the proposed and candidate species and proposed critical habitat. In the future, upon listing of the species or designation of critical habitat, the EPA can request the Service adopt the conference Opinion as a biological Opinion to satisfy the EPA's 7(a)(2) requirement.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the ESA directs federal agencies to use their authorities to further the purposes of the ESA by carrying out conservation programs for the benefit of the endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of an Action on ESA-listed species or critical habitat, to help implement recovery plans, or develop information (50 C.F.R. §402.02).

EPA's implementation of the following conservation recommendations would provide information and support for future consultations involving upcoming FIFRA registrations authorizing use of pesticide active ingredients that may affect ESA-listed species and critical habitats:

1. Improve reporting by initiating an interagency committee to work with stakeholders and other interested parties to devise a methodology(s) or programs to better understand and more comprehensively track usage of chemicals in the field. Implementation of methodologies or programs for tracking usage may include various tasks. For example, one option may include setting up or overseeing a volunteer data collection program regarding agricultural and non-agricultural pesticide usage.

2. Develop a conservation program for endangered and threatened species in collaboration with stakeholders and Agencies that specifically addresses threats to listed species and how implementation of FIFRA programs and collaboration with pesticide registrants and other stakeholders can help to ameliorate those threats.

3. Develop a conservation banking, in-lieu fee, and/or environmental market-based initiative, through a cooperative effort with pesticide registrants and stakeholders, designed to voluntarily offset impacts to listed species and designated critical habitats from multiple pesticides that may pose similar threats.

4. Work with other appropriate federal, state, and local partners to study the efficacy of conservation practices in reducing pesticide loading to streams, lakes, wetlands, sinkholes, and other terrestrial and aquatic habitats from off-site transport. Topics may include the width, structure and complexity of buffer strips, swales, riparian areas, other vegetation types, use of in field native vegetation buffers and cover crops, precision agriculture technologies and other strategies that have the potential to reduce adverse impacts to listed species.

5. Develop methods and models that better describe and quantify pesticide persistence and fate and transport to assist in analyses for future pesticide consultations. For example, models may be used to better quantify pesticide persistence in freshwater and terrestrial environments that correlate to mortality or sublethal effects. Similarly, improving capabilities to model pesticide fate and transport at the watershed scale would help to inform future analyses.

6. Develop methods to better understand and quantify pesticide exposure from methomyl non-agricultural uses.

7. Develop criteria that address when pesticide-contaminated sediment is an important route of exposure to aquatic or terrestrial organisms.

8. Sponsor additional research to support new technological devices or procedures to further reduce effects to ESA-listed resources.

9. Work with stakeholders and growers to develop conservation guidelines.

10. Facilitate outreach to large growers so they are educated about the issues and work with the agencies to minimize impacts to listed species and critical habitat.

REINITIATION NOTICE

Issuance of a final Biological Opinion will conclude formal consultation on the proposed action outlined in the request. As provided in 50 CFR 402.16, reinitiation of formal consultation is required and shall be requested by the federal agency or by the Service, where discretionary federal agency involvement or control over the action has been retained or is authorized by law and: (1) If the amount or extent of taking specified in the incidental take statement is exceeded; (2) If new information reveals that effects of the action may affect listed species or critical habitat in a manner or to an extent not previously considered; (3) If the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the Biological Opinion or written concurrence; or (4) If a new species is listed or critical habitat designated that may be affected by the identified action.

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